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Apple's powerhouse tablet examined

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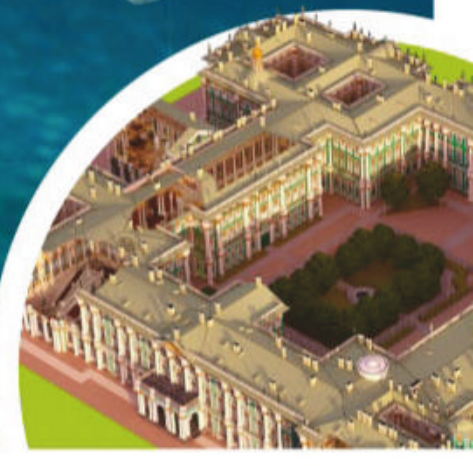
Inside the home of the Russian Revolution



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WELCOME

The magazine that feeds minds!

David Attenborough created quite a stir in 2017's *Blue Planet II* with that iconic shot of a sperm whale with a large piece of plastic stuck in its mouth, and not a moment too soon. Find out on page 22 how we're choking the oceans with the wonder material/environmental disaster that is plastic, and what we're doing to solve the problem. This issue we also explore a possible future of medicine in the form of electroceuticals, the electronic pharmaceutical alternative. Then it's off to wander the many rooms of Russia's Winter Palace, discover the many reasons why humans and animals lie, and learn how telerobotics allow scientists to explore the surface of new worlds. Also new this issue: my face. As Editor, I'm really looking forward to curating and crafting your regular dose of science and technology. Enjoy!

Ben Biggs
Editor

"How did these predators go from feral to friendly modern-day pets?"

The World of Wildcats, page 42

Meet the team...

Charlie G
Production Editor
I've always been fascinated by Russia's blood-soaked past, so I thoroughly enjoyed the Winter Palace feature. Head to page 72 comrades!

Baljeet
Research Editor
Discover how robotic avatars will revolutionise our future exploration of other planets and space on page 58.

Charlie E
Staff Writer
Explorers have circumnavigated the world using bicycles, ships, planes and even submarines! Find out more on page 64.

Scott
Staff Writer
From forest perimeters to the deep desert, wild cats can be found across the globe. Discover the diversity of these felines on page 42.

Duncan
Senior Art Editor
Getting a prescription from a robot and then swallowing a small microchip to cure ailments might be in our near future. Find out on page 32.

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MEET THIS ISSUE'S EXPERTS...

James Horton
Former **HIW** member James is a biochemist and biotechnologist. He is currently doing a PhD in machine learning and evolutionary theory.

Jo Stass
Jo has been a writer and editor for over six years. She is particularly interested in the natural world and technological innovations.

Jodie Tyley
The former Editor of **HIW** and **All About History** has tackled many topics in her career, from science fiction to science fact and Henry VIII to honey badgers.

Jonathan O'Callaghan
With a background in astrophysics, former **HIW** and **All About Space** journalist Jonathan enjoys delving into the wonders of space.

Laura Mears
Biomedical scientist Laura escaped the lab to write about science and is now working towards her PhD in computational evolution.

Stephen Ashby
Stephen has been a writer and editor for over seven years. He is endlessly intrigued by technology and Earth science.

Steve Wright
Steve has worked as an editor on many publications. He enjoys looking to the past, having also written for **All About History** and **History Of War**.

Tim Williamson
History Of War
Editor Tim has a passion for all things military but studies and writes about a range of historical eras.

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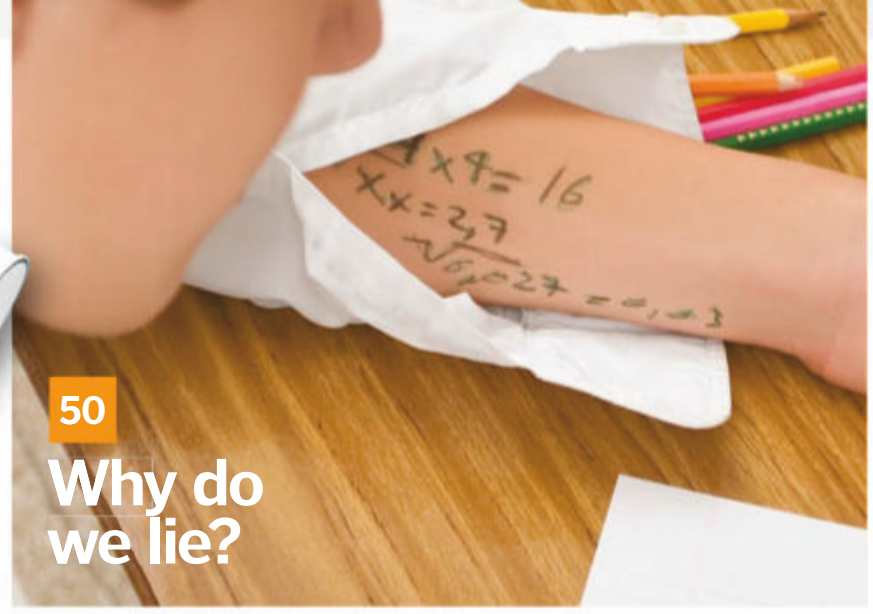
The future of medicine



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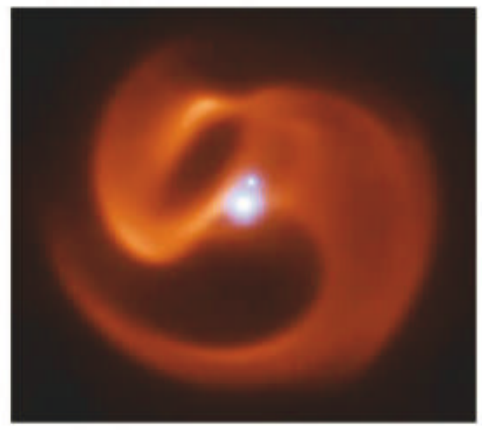

REGULARS

Tom Lean
Tom is a historian of science at the British Library working on oral history projects. His first book, *Electronic Dreams*, was published in 2016.

Victoria Williams
Evolutionary biologist and **World of Animals** writer Vicky is fascinated by the natural world and happiest when she's outdoors.

Sifakas ‘dance’

These three Verreaux’s sifakas (*Propithecus verreauxi*) are one of many lemur species that are native to Madagascar. While they spend most of their time in the trees, hanging and swinging with all fours, when they do venture down to the ground they hop on two legs. This comical movement is why they are often described as ‘dancing’ lemurs.

Glowing surprises

This image from the ESO's Very Large Telescope reveals the unexpected abundance of atomic hydrogen clouds that surround distant galaxies. The telescope's extremely sensitive MUSE spectrograph uncovered the otherwise invisible glow.

A closer look at sugar

These translucent shards are magnified brown sugar crystals. They consist of sucrose molecules – a combination of the simple sugars fructose and glucose – arranged in an orderly pattern to create tiny cuboid structures.

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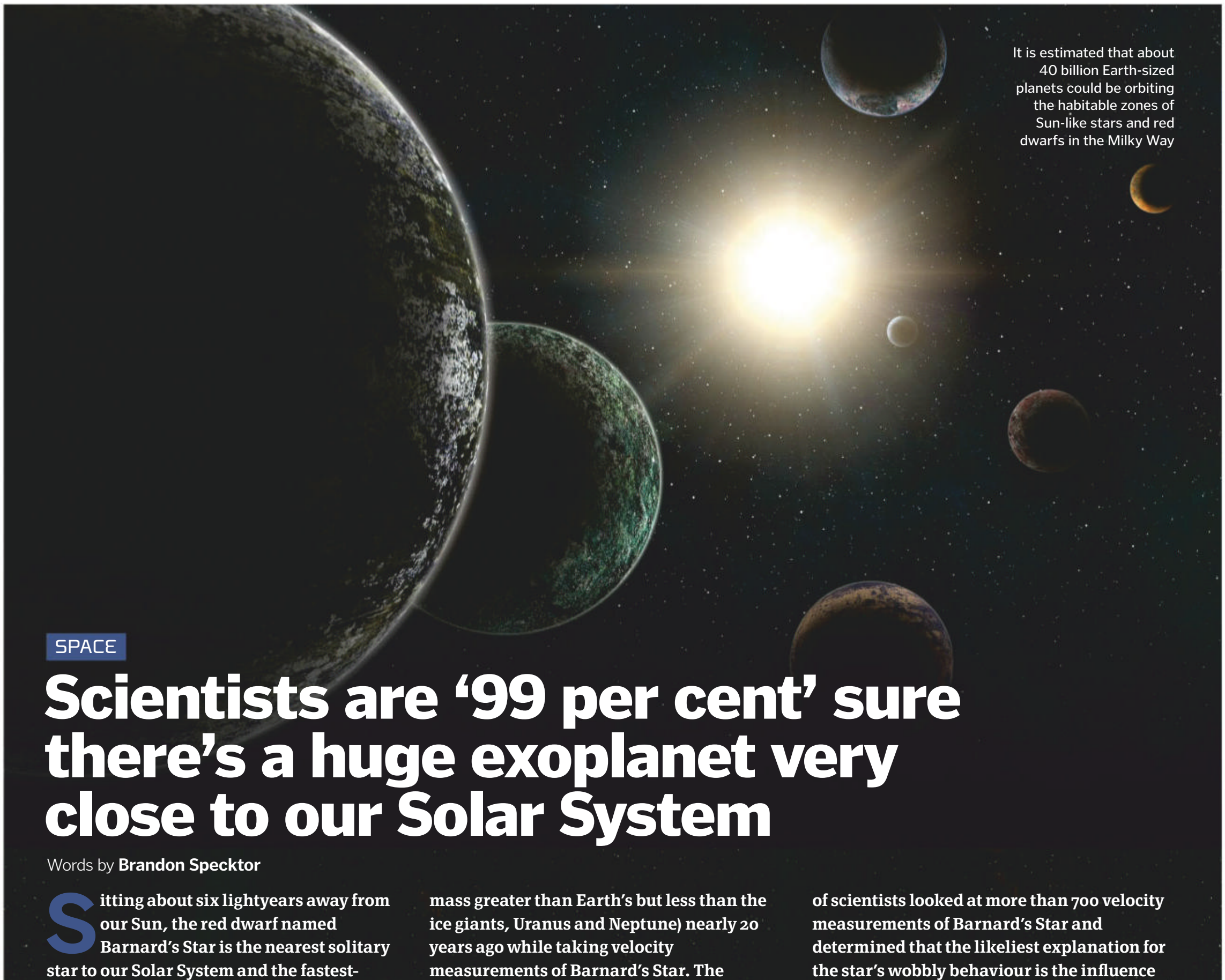


It is estimated that about 40 billion Earth-sized planets could be orbiting the habitable zones of Sun-like stars and red dwarfs in the Milky Way

SPACE

Scientists are '99 per cent' sure there's a huge exoplanet very close to our Solar System

Words by **Brandon Specktor**

Sitting about six lightyears away from our Sun, the red dwarf named Barnard's Star is the nearest solitary star to our Solar System and the fastest-moving star in our night sky. It's also really, really wobbly.

It may be that the wobbles can be chalked up to old age: the star may have been born some 10 billion years ago – making it more than twice the age of our Sun – and it has only 16 per cent of the Sun's mass. But astronomers prefer a different explanation. A new paper published in the journal *Nature* combines 20 years of research to conclude "with 99 per cent confidence" that Barnard's Star is being tugged about its orbit by a nearby exoplanet – a world that's roughly three times the size of Earth and loaded with ice.

Astronomers caught wind of this possible super-Earth (that is, an exoplanet that has a mass greater than Earth's but less than the ice giants, Uranus and Neptune) nearly 20 years ago while taking velocity measurements of Barnard's Star. The scientists saw that every 230 days or so Barnard's Star seemed to wobble its way closer to our Solar System before slowly retreating again. The presence of a large planet, which could exert its own gravitational influence on Barnard's Star as it orbits around its host, was a possible explanation. Still, more data was needed to say for certain.

Now, following 20 years of observations from telescopes around the world, the data is there. In a new study, an international team of scientists looked at more than 700 velocity measurements of Barnard's Star and determined that the likeliest explanation for the star's wobbly behaviour is the influence of a nearby planet orbiting its local sun every 233 days.

According to study co-author Cristina Rodríguez-López, researcher at the Instituto de Astrofísica de Andalucía, this discovery represents "a boost to continue on searching for exoplanets around our closest stellar neighbours, in the hope that eventually we will come upon one that has the right conditions to host life".

The planet has no atmosphere and its surface is likely to be rocky, barren and extremely cold at around -170°C

PLANET EARTH

These ancient termite mounds are as old as the Egyptian pyramids – and they're visible from space

Words by **Laura Geggel**

Termites build some of the most impressive structures in the animal kingdom

Around the same time the ancient Egyptians were building their mighty pyramids, tiny termites were digging through the earth, creating giant mounds in Brazil that still exist today and are so massive they're visible from space.

The roughly 4,000-year-old termite mounds – there are about 200 million of them – are so immense that each has nearly 50 cubic metres of soil in it. Taken together, these termites have excavated more than ten cubic kilometres of earth, equivalent to the volume of about 4,000 Great Pyramids of Giza, researchers have said.

In other words, this is to date the "greatest known example of ecosystem engineering by a single insect species," the researchers wrote in the study.

The termite-crafted mounds are located in northeastern Brazil and span an area about the size of the UK, the researchers said. But these mounds – measuring about 2.5 metres tall, with a diameter of around nine metres – aren't nests, the researchers explained.

Over thousands of years generations of these industrial termites (*Syntermes dirus*) worked relentlessly to excavate vast amounts of dirt as they made an extensive, interconnected tunnel system underground. Then they dumped the dug-up soil above ground, thereby forming the towering mounds we see today.

"These mounds were formed by a single termite species that excavated a massive network of tunnels to allow them to access dead leaves to eat safely and directly from the forest floor," said Stephen Martin, the chair of social entomology at the University of Salford, UK.

PLANET EARTH

Are these Earth's oldest fossils of life? Row has huge implications

Words by **Tom Metcalfe**

Scientists will gather in a remote and snowy part of southwestern Greenland next summer to try to determine if rocks from 3.7 billion years ago contain some of the oldest fossils of life on Earth — with implications for the search for evidence of life on Mars.

Tiny, triangular structures found in these rocks have been a source of controversy, with some scientists saying they are not evidence of early life on Earth, while the scientists who first reported that they were fossilised evidence of life are defending their claims.

In a paper published online on 17 October in the journal *Nature*, planetary scientist Abigail Allwood and colleagues, who examined the ancient rocks in Greenland, reported that purely geological processes could explain the triangular rock formations, and that while they might still be formed by microbial life, there was not enough evidence to show definitely that they were.

The rocks found in Greenland may be the oldest in the world, but not all researchers agree

HISTORY

North America's oldest mummy sheds light on ancient migrations

Human remains from P W Lund's collection from Lagoa Santa, Brazil, are kept in the Natural History Museum of Denmark

Words by **Megan Gannon**

Dressed in moccasins and a rabbit-skin shroud, a man was laid to rest in a cave in Nevada about 10,600 years ago. Now, his mummy is helping scientists fill in the picture of how humans first migrated into the Americas.

Scientists have sequenced the genome of the Spirit Cave Mummy – the oldest human mummy found in North America – along with 14 other ancient individuals from the Americas. The genome revealed the mummy's Native American ancestry, which has allowed his living descendants to properly bury him.

The similarities in the DNA from people who lived as far north as Alaska and as far south as Patagonia suggest the continent's first settlers spread out quickly, according to the study published on 8 November in the journal *Science*.

"These findings imply that the first peoples were highly skilled at moving rapidly across an utterly unfamiliar and empty landscape," study co-author David Meltzer of Southern Methodist University said. "They had a whole continent to themselves, and they were travelling great distances at breathtaking speed."

The Americas were the world's last big land masses to be colonised by humans. For much of the 20th century scientists thought they had a solid explanation for how this migration happened: hunter-gatherers living in Siberia chased large game like mammoths across the Bering Land Bridge. After the end of the last ice age melting glaciers opened an ice-free corridor, allowing these pioneers to spread south.

However, the story of the peopling of the Americas has become more complex in the last few decades. Archaeologists have discovered campsites, such as Monte Verde in Chile, that pre-date the ice-free corridor, which is thought to have opened around 13,000 years ago. Some scholars have proposed that the first Americans could have arrived along the Pacific coast by boat. New DNA evidence has also offered clues about the origins of the early populations, but until now sample sizes of ancient genetic material from North America have been small.

STRANGE NEWS

Doctors retrieve spoon from man's oesophagus – a year after he swallowed it

Words by **Mindy Weisberger**

A man in China had a steel spoon lodged in his oesophagus for a year, but surprisingly the half-swallowed utensil didn't cause too much discomfort.

The man – identified only as 'Mr Zhang' – swallowed the spoon for a dare in 2017, and it promptly got stuck in the narrow tube connecting his mouth and stomach, representatives at Xinjiang Meikuang General Hospital said in a statement. Months passed, but the irritation wasn't serious enough to prompt the man to seek medical attention. That all changed recently though when he began experiencing chest pains and difficulty breathing after being punched in the chest.

Three doctors performed the procedure to remove the spoon on 22 October. Two hours later, the spoon – which measured about eight inches (20 centimetres) long – saw the light of day for the first time in a year, hospital officials reported.

The man spent one year with the spoon embedded in his gullet

Fiery secrets locked below the ice could offer answers to our planet's past

PLANET EARTH

There's something hot hidden under East Antarctica

Words by **Rafi Letzter**

Something warm lurks beneath the frozen wastes of East Antarctica, and scientists aren't sure precisely what it is – but they have a pretty good idea.

East Antarctica is a craton, a big, continent-sized chunk of Earth's crust. It's solid and thick. It's not supposed to let heat through from inside the Earth. (That makes it different from the thinner crust of West Antarctica, where magma is, in some places, quite close to the surface.)

That craton means that East Antarctica shouldn't have much melted water at the bottom of its ice sheet. However, as researchers revealed in a paper published on 14 November in the journal *Scientific Reports*, there is an unusually high amount of melted water down there. This melt isn't related to climate change, which causes intense melting at the fringes of the continent; it's an old and separate warm spot in the ice, insulated and kept far away from the atmosphere. Scientists were able to detect it thanks to a survey that used specialised ice-penetrating radar.

It's not entirely clear what causes the warmth down there (the craton should protect the ice from the Earth's inner heat), but the research team offered an educated guess: hydrothermal energy. A fault in the crust down there might be full of water, pulsing up and down between the warm depths of the Earth and the bottom of the ice. It could be providing a conduit for heat to escape and thereby trigger melting.

> *"It may contain some of the planet's oldest ice, important records of climatic transitions"*

This hidden heat source is of course interesting in its own right, but the researchers wrote that it's especially important because it might influence data used to understand the planet's deep past.

"This is an area of interest," they wrote, "as models suggest it [East Antarctica] may contain some of the planet's oldest ice, preserving records of important climatic transitions."

Researchers take core samples of that old ice and use them to understand how the planet's atmosphere has changed over time. Each layer of ice functions as a record of the planet's air from the period when it formed. Understanding the circumstances under which that ice sat over the millennia since can help researchers improve their understanding of that data.

HISTORY

Ice-age cave art found under layers of centuries-old graffiti

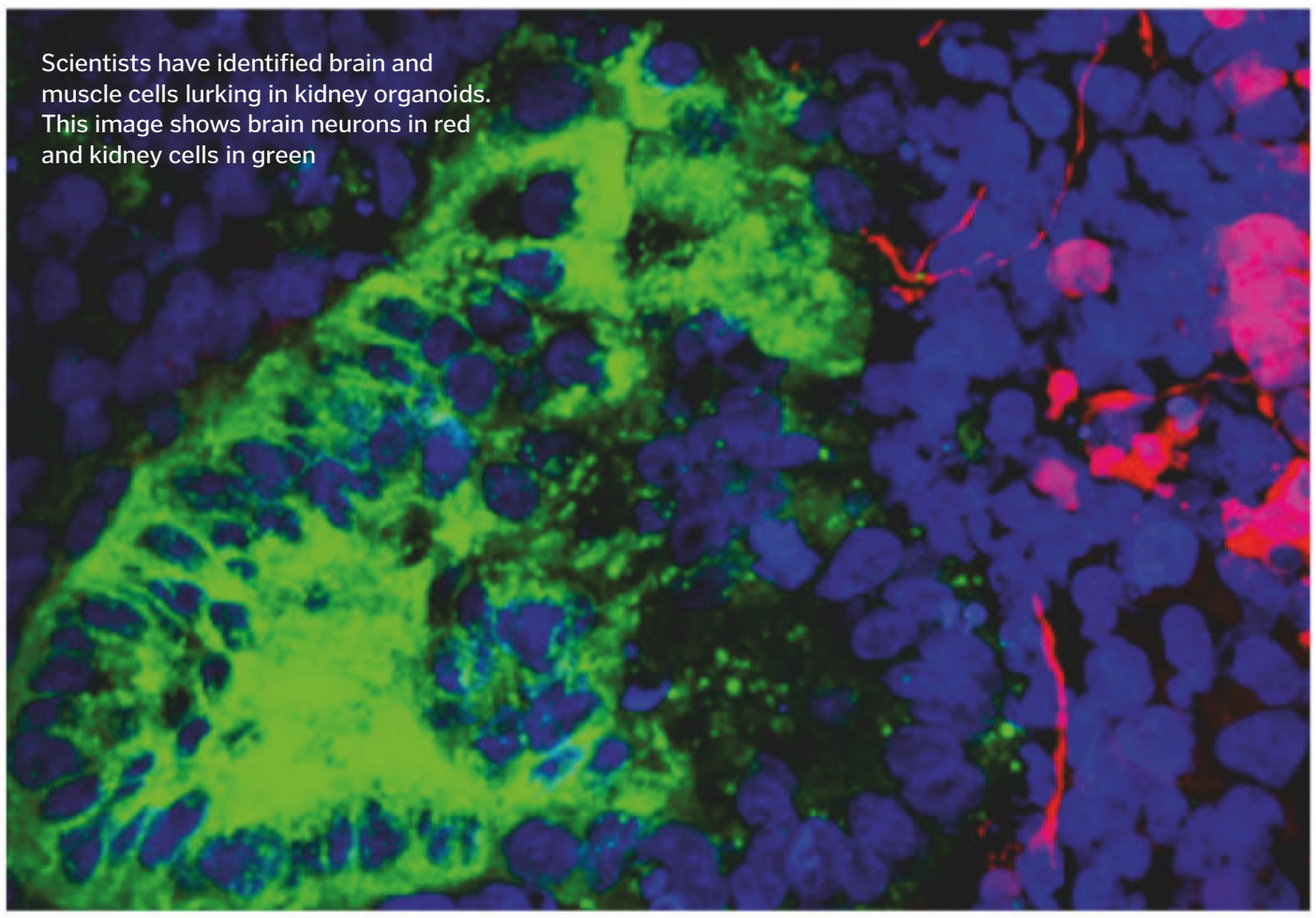
Words by **Mindy Weisberger**

Archaeologists had long suspected that two caves called Grottes d'Agneux located in eastern France might harbour artwork produced thousands of years ago by human artists. The researchers had strong suspicions that the art was there, but the cave walls were so covered with layers of more recent graffiti (from the 16th to 19th centuries) that the ancient art had likely been hidden for hundreds of years, representatives of the University of Tübingen in Germany reported in a statement.

Scientists with the university and researchers from Spain recently used scanning technology to peer through the graffiti layers, reconstructing carved prehistoric images of a horse and a deer buried underneath. After scans revealed the figures, the scientists reconstructed the artwork with image-processing software. They then used carbon-14 dating of charcoal in the cave and in the art to reveal the age of the paintings.

Carbon-14, a carbon isotope, breaks down over time. By examining how much of the isotope in an object has decayed, scientists can calculate how old the object is; in this case, the art was found to be 12,000 years old.

This is the carved outline (highlighted) of a prehistoric deer or reindeer in the Agneux II cave, Rully, Saône-et-Loire, France



Scientists have identified brain and muscle cells lurking in kidney organoids. This image shows brain neurons in red and kidney cells in green

HEALTH

Lab-grown mini kidneys 'go rogue' and sprout brain and muscle cells

Words by **Mindy Weisberger**

Miniature lab-grown kidneys have been hiding something from the scientists who grew them. Instead of developing into different varieties of kidney cells, some of the cells took a different path and became brain and muscle cells.

These simple mini kidneys, also known as kidney organoids, are grown from stem cells that are encouraged to develop into clusters of specific kidney cells. The scientists set out to grow kidney organoids in the lab and then analyse them to see what was happening inside of them on a cellular level. They expected to see a diverse variety of kidney cells, comparable to what one would see in a normal, fully grown human kidney, but they discovered that ten per cent to 20 per cent of the organoids' cells were not kidney cells at all but brain and muscle cells.

"The appearance of these cells can spell trouble for researchers modelling diseases"

To identify the cellular makeup of their four-week-old mini kidneys, the study authors used a technique known as single-cell RNA sequencing, which examines activity in individual cells rather than in cell populations. This provides a more detailed view of individual cell identity and function. In this case it revealed that some of the mini kidneys' cells were in fact brain and muscle cells. The appearance of these cells can spell trouble for researchers who use kidney organoids to model diseases, "because when off-target cells appear in an organoid, it means that it doesn't faithfully model a human kidney," co-author Benjamin Humphreys, chief of the Division of Nephrology at Washington University School of Medicine in St. Louis told **Live Science**.

After analysing the cell receptors in growing organoids, the scientists discovered that they could inhibit the signalling pathways of rogue cells, cutting down on the number of brain cells by about 90 per cent. Future research strategies could focus on fine-tuning the signals that a developing kidney organoid sends to its cells as they differentiate, "to make cells behave more like mature adult kidney cells," Humphreys said.

SPACE

This star system might blast gamma rays into the Milky Way when it dies

Words by **Rafi Letzter**

For the first time, astronomers have found a star system in our galaxy that could produce a gamma-ray burst – one of the brightest and most energetic events known to occur in the universe.

The star system is officially called 2XMM J160050.7–514245, but the researchers nicknamed it 'Apep' after the Egyptian snake deity of chaos. The name works nicely for the system, which is surrounded by long, fiery pinwheels of matter cast out into space. Those pinwheels come from a pair of tightly orbiting binary 'Wolf-Rayet' stars at the system's centre. Wolf-Rayet stars are supermassive suns that have reached the ends of their lives and burned up all their hydrogen. They thus fuse heavier elements, spinning rapidly and tossing material into space. They're bright enough that astronomers can detect their presence even when they reside in other galaxies. When their cores collapse, triggering supernovae, astronomers believe they may create the long gamma-ray bursts sometimes detected from deep space.

In a paper published in the journal *Nature Astronomy*, researchers report that Apep is a good candidate for such a burst, making it the first star system of its kind discovered in the Milky Way. Those long pinwheels, the researchers wrote, result from stellar winds moving away from the binary system at an incredible 2,100 miles per second (about 3,379 kilometres per second).

It's unclear precisely what causes stars of this kind to spin so fast, but that speed will play a key role in producing a gamma-ray burst when the supernova eventually comes, the researchers said. And that time should come soon, in cosmic terms. Wolf-Rayet stars tend to live in this fast-spinning state for just a few hundred thousand years.

Apep's stellar streams coil around the knot of orbiting stars at its core, captured by the ESO's Very Large Telescope

PLANET EARTH

Invisible stew of plastic pollution found in fur seal faeces

Words by **Stephanie Pappas**

Scientists have found plastic microfibres smaller than one millimetre in length in the faeces of fur seals on Guafo Island (located off the west coast of Chile). It's the first discovery of these tiny fragments of plastic in wild animal scat researchers reported in the November issue of the journal *Marine Pollution Bulletin*.

The researchers scoured Guafo Island, scooping up seal dung from the fur seals that use it as a breeding ground. Of the 51 samples collected at Guafo Island and analysed by the researchers, 67 per cent had these miniscule fibres inside. There were between about three and 13 fibres per gram overall, corresponding to a range of up to 180 fibres per stool sample.

Fur seals are top ocean predators, so the microfibres in their digestive systems probably come from plastics accumulated from the bottom up. The fibres get consumed by plankton, which are then eaten by crabs and fish, fur seals' main meals.

www.howitworksdaily.com

Plastic pollution has reached some of the ocean's top predators in South American fur seals

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Syncing everyone's FitBit in the app is a great way to motivate the family to be more active

REVIEW

Fitbit Ace review

Words by **Damien McFerran**

The FitBit Ace offers the right level of functionality suitable for kids and young teenagers

Having conquered the world of adult fitness trackers, Fitbit has now turned its attention to its next target: children.

The Fitbit Ace is the first product from the company to focus solely on youngsters, a market that has grown significantly over the past few years. Competitors have sprung up in the children's activity tracker space, and the Fitbit Ace is the first time the company has tried to tackle the younger market.

The term 'My First Fitbit' is very apt here; the Ace is aimed at kids who have never used a fitness tracker before and want some very basic incentive to get on their feet and burn some energy. But the Ace doesn't compromise on core features either – it offers water resistance, activity tracking, decent stamina and robust connectivity with the core Fitbit smartphone app. The Ace uses a 128 x 36 pixel resolution OLED screen to display information such as the time, date, total steps for the day and total active time.

The ergonomically shaped main body is comfortable enough, even though it's made out of metal, while the strap itself is a soft, rubber-like material that didn't cause any complaints during our testing period. You can get the device with either a blue or purple strap.

The device is marketed as being for kids aged eight and up, but the changeable strap means even teenagers will be able to get some use out of it before upgrading to the real deal.

If you're concerned that your child isn't active enough then the Fitbit Ace is a good way of 'gamifying' exercise. The screen also handles all of the notifications that relate to various activities, and does a good job of displaying eye-catching animations, which give kids a visual reward for hitting their goals. Unlike a lot of OLED-based wearables, the screen is easy to make out in direct sunlight. The only downside is that because interaction is based around tapping and not touch, it can take some getting used to. A firm tap anywhere on the tracker is usually required to wake the screen, and subsequent taps will cycle through the various displays. If you just want the time, tilting your wrist is enough to wake the display.

With its reduced feature set and child-friendly reward system, the Fitbit Ace is the perfect device for parents who want to get their kids active without dazzling them with the full force of fitness tracking.

■ $99.95 / £79.99

⊕ Good design for kids.
Changeable straps.
Smart app skills.

⊖ Expensive compared to competition.
Limited functionality compared to other Fitbit.
Easier if you own a Fitbit.

★★★★☆

The 100 per cent sRGB colour gamut helps the display to just pop with a wide variety of colours supported at impressive accuracy

REVIEW

Razer Blade (2018) review

Words by **Joe Osborne**

Razer knocked it out of the park when it comes to the Razer Blade's display and its 144Hz refresh rate

The 2018 Razer Blade marks a huge revolution for a thin and light device that is already one of the best gaming laptops. This time, Razer has abandoned the 14-inch model for, well, another 14-inch Razer Blade, technically speaking. With the Razer Blade 2018, Razer managed to shove a 15.6-inch display into a 15-inch frame, kind of like we've seen in some of the best Ultrabooks. This has resulted in the smallest 15-inch gaming laptop ever, at least according to Razer.

It's been completely redesigned from the ground up, and we have to admit, the new Razer Blade is pretty impressive. However, the new Razer Blade has arrived in a gaming laptop scene that's changed so much over the last year. In the span of a year, the competition has created a wealth of gaming laptops similar to this one, making it hard for the Razer Blade 2018 to stand out. Nevertheless, Razer has crafted its most attractive and alluring laptop yet with the latest Blade, but unfortunately it still suffers from some basic flaws seen in both other gaming laptops as well as Razer's own previous efforts.

This gaming laptop will get you further than most in terms of fps and smoothness, with its overclocking mode and 144Hz display. However, lacklustre battery life and some seriously hot temperatures, not to mention the omission of Windows Hello support and a mildly goofy keyboard layout give us pause, especially considering the expectedly lofty price tag. What you have here, then, is an incredibly stylish and good-feeling laptop, one that this editor would even consider paying a premium for, that is held back by some flaws that are tough to ignore. Razer is clearly at the top of its game with the latest Blade, but the rest of the gaming laptop world is clearly catching up.

From £1,699 / $1,899

- ⊕ Beautiful new design.
- ⊕ Excellent screen.
- ⊕ Fantastic performance.
- ⊖ Heats up under pressure.
- ⊖ Poor battery life.
- ⊖ Surprisingly dense.
- ⊖ No Windows Hello.

★★★★☆

WISH LIST

The latest must-have technology

Apple Watch Series 4

■ Price: **From £399 / $399** www.apple.com

With all of the functionality of a fitness tracker, the Apple Watch Series 4 is fantastic for people who want to make real changes to their lifestyle. Whether you want to drink more water, improve your sleep or better manage a condition like diabetes, this piece of tech is designed to help you achieve your health goals. The super smart tech monitors your heart rate, alerts you when it is too high or too low, and tracks how much you exercise and how many calories you burn. There's even an inbuilt safety feature to call the emergency services if you have a fall.

Chameleon water bottle

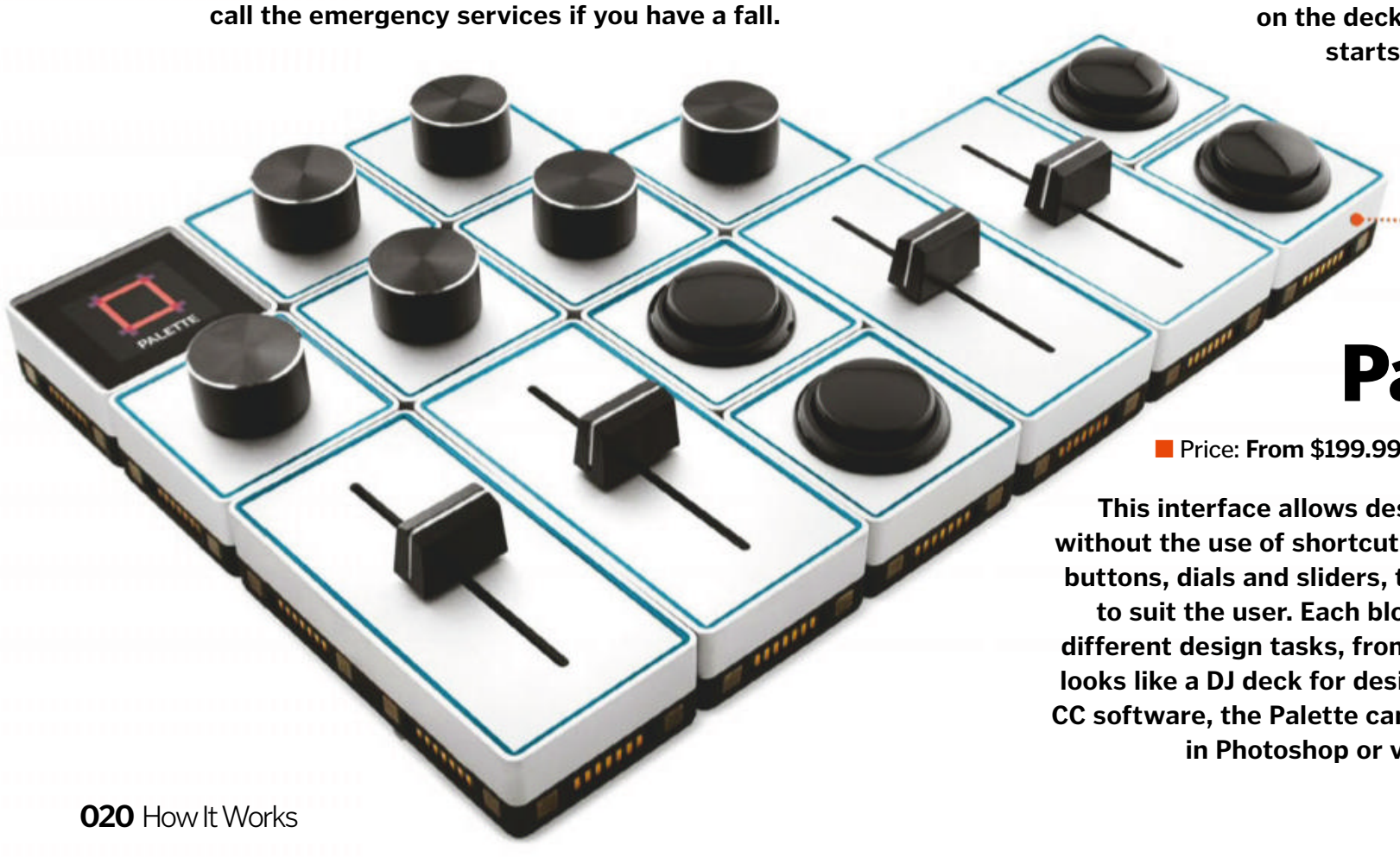
■ Price: **£22 / (approx. $30)** www.root7.com

Is your water bottle half empty or half full? With the new Chameleon water bottle from Root 7 you'll be able to see exactly how much of your drink is left thanks to their colour-changing technology. A fun way to motivate adults and kids to drink more water and a great way to reduce how much plastic you use, the Chameleon is available in three colours: peach, blue and purple. Available to purchase from January 2019.

Native Union Wireless Charger

■ Price: **£49.99 / $59.99**
www.nativeunion.com

If you're bored of rooting around looking for the right phone charger and tired of broken wires or fried charging ports, the new Native Union Wireless Charger is a product you'll love. Compatible with all Qi-compatible devices, this charger is a game-changer, and it means you won't ever need to plug your phone in to charge again. Instead, just place your phone on the deck and the Native Union Wireless Charger starts charging straight away. This charger is simple to use, has fast charging times and an easily portable design, and we love being able to finally ditch our old chargers!



Palette

■ Price: **From $199.99 (approx. £160)** www.palettegear.com

This interface allows designers to take control of their work without the use of shortcuts. As a set of interchangeable blocks of buttons, dials and sliders, the Palette is completely customisable to suit the user. Each block can be programmed to carry out different design tasks, from resizing to a simple undo, the Palette looks like a DJ deck for design. Compatible with an array of Abobe CC software, the Palette can be the perfect assist for image design in Photoshop or video editing in Premiere Pro.

Timeular

■ Price: **From approx. £90 / approx. $110** www.timeular.com

If you struggle to keep track of your working day then this is the gadget for you. Sometimes organising our life can be difficult, but the Timeular makes time management simple. Each side of the diamond is customisable to a particular task via the accompanying app. By turning the diamond the upward-facing task will begin to record the time until it's turned to the next task, which again will begin to record time spent on that task. Data about your daily activity is stored, creating a breakdown of your day.

Nuraphone

■ Price: **£349 / $399** www.nuraphone.com

Sound becomes completely personalised with these innovative headphones. Alongside a unique dual method of sound delivery – both canal phones and over ear – Nuraphone learns how best to deliver your ear sound to create an immersive experience. Through a Bluetooth connection the companion app displays your hearing profile, adjustable immersion and sound cancellation levels. The Nuraphone is a fresh new take in a market saturated with products, delivering sound clarity and immersion few can compete with.

APPS & GAMES

Solar System Scope

■ Developer: **INOVE, s.r.o.**

■ Price: **Free / Google Play / The App Store**

Explore our Solar System with this immersive app. As a 3D encyclopaedia the app is packed with amazing information, and when pointed at the sky it will take your location and give you information about the constellations above you.

Animal Tracker

■ Developer: **Max Planck Society**

■ Price: **Free / Google Play / The App Store**

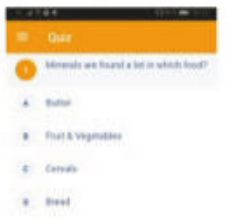
With this clever tracker app you can find out the precise location of wild animals anywhere in the world. From monitoring bird migrations to the movements of individuals like Bonnie the buzzard in near real time.

Gojimo Revision

■ Developer: **Telegraph Media Group**

■ Price: **Free / Google Play / The App Store**

Don't leave your revision to the last minute! With over 160,000 free revision quiz questions on English, maths, biology, chemistry, physics, history, geography and more, the Gojimo Revision app has everything you need for a head start on your exams.



Sleep cycle

■ Developer: **Sleep Cycle AB**

■ Price: **Free / Google Play / The App Store**

This intelligent alarm clock analyses your sleep cycles and wakes you up in the morning when you are in your lightest phase of sleep, thereby helping you to feel more awake and ready to face the day to come.

HOW WE WILL FIX THE PLASTIC PROBLEM

Plastic waste is choking the planet. What can we do to clean the trash from the oceans?

Words by **Laura Mears**

Somewhere between Hawaii and California, a vast inflatable coastline sweeps through the sea. Beneath a 600-metre-long float, a three-metre deep skirt rakes the ocean. Forced along by wind and waves, it moves faster than the currents, bending as it travels to form a U-shaped net. Fish dive beneath to escape its advances, but as the system roams the water it gathers a strange catch. Braving gales and storms and resisting the corrosive effects of sea salt, System 001 sends signals to satellites overhead and boats close by to collect a haul unlike any other. This net is trawling the great Pacific Garbage Patch, and its job is to clean up the sea.

The Pacific Garbage Patch is a trash vortex; a swirling gyre of waste caught up in ocean currents. While not the literal island of rubbish sometimes described in the media, its waters are strewn with small chunks of floating debris. Churned by the action of the waves, the pieces bob up and down in the water column, circulating with the currents. Invasive species hitch a ride on the travelling plastics, making their way to waters nature never intended for their occupation. Sea birds, marine mammals and fish mistake the floating chunks for food, filling their bellies with indigestible trash. The pieces that remain wear away under the relentless rocking, rubbing microscopic plastic splinters and toxic chemicals into the water.

> *"The Pacific Garbage Patch is a trash vortex"*

Deployed on 16 October 2018, System 001 aims to clear half of the rubbish from the Pacific Garbage Patch over the next five years. It is the first of a network of 60, and the result of more than 270 scale model tests and six prototypes. Pushed along by natural forces and equipped with solar-powered electronics, System 001 quietly follows the flow of the water. It's got lights and GPS to warn sailors, and it moves slowly enough that fish

The plastic problem

How does plastic get out into the environment?

1 Constant consumption
The world produces 300 million tons of plastic each year, half of which we use just once before discarding it.

2 Contaminated water
Over 110,000 tons of microplastics wash over agricultural land in North America and Europe every single year.

3 In the laundry
Acrylic clothes release over 700,000 plastic fibres per 6kg wash. Polyester releases nearly 500,000.

4 Plastic per person
The average person in the EU makes 31kg of plastic waste every year.

5 Microplastic soup
There are more than 5 trillion pieces of plastic floating about in the oceans.

6 Rivers of rubbish
Our rivers carry around 100,000 rubbish trucks' worth of plastic waste out to sea each year.

7 Out to sea
12 million tons of plastic makes it out into Earth's oceans via rivers, beaches and drains every year.

8 On the beaches
For every mile of UK beach you can expect to find 5,000 pieces of discarded plastic waste.

have plenty of time to get out of the way. Plastic, on the other hand, can't escape: trapped between the inflatable float and the solid skirt, it has nowhere to go. Load by load, sea-going rubbish trucks will retrieve the waste and start to clear the ocean. If all goes well, the project could roll out across the globe to remove 90 per cent of our floating junk by 2040.

HOW DID WE GET HERE?

It's barely more than 100 years since Leo Baekeland invented the first fully synthetic plastic. Developed to insulate electrical wires at the tail end of the second industrial revolution, this new material was unlike anything seen before. Cheap to produce, resistant to heat and highly mouldable, it could be anything people wanted it to be, and its appearance kick-started a wave of chemical innovation.

All plastics have the same basic structure. Zoom in and most look like strings of pearls, with long, repeating chains that melt when they heat up and set hard as they cool. What makes them special is their versatility. We can extrude them into thin sheets, press them between rollers, blow them into bubbles, cast them like metal or vacuum mould them into 3D shapes. Changing the chemical building blocks of the chains can alter their flexibility, melting point and ability to resist chemicals. Additives between the chains can change their colour, make them fire-proof or kill bacteria, and adding branches to the chains can make them tangle, forming knots that don't melt and locking finished plastics into permanent shapes.

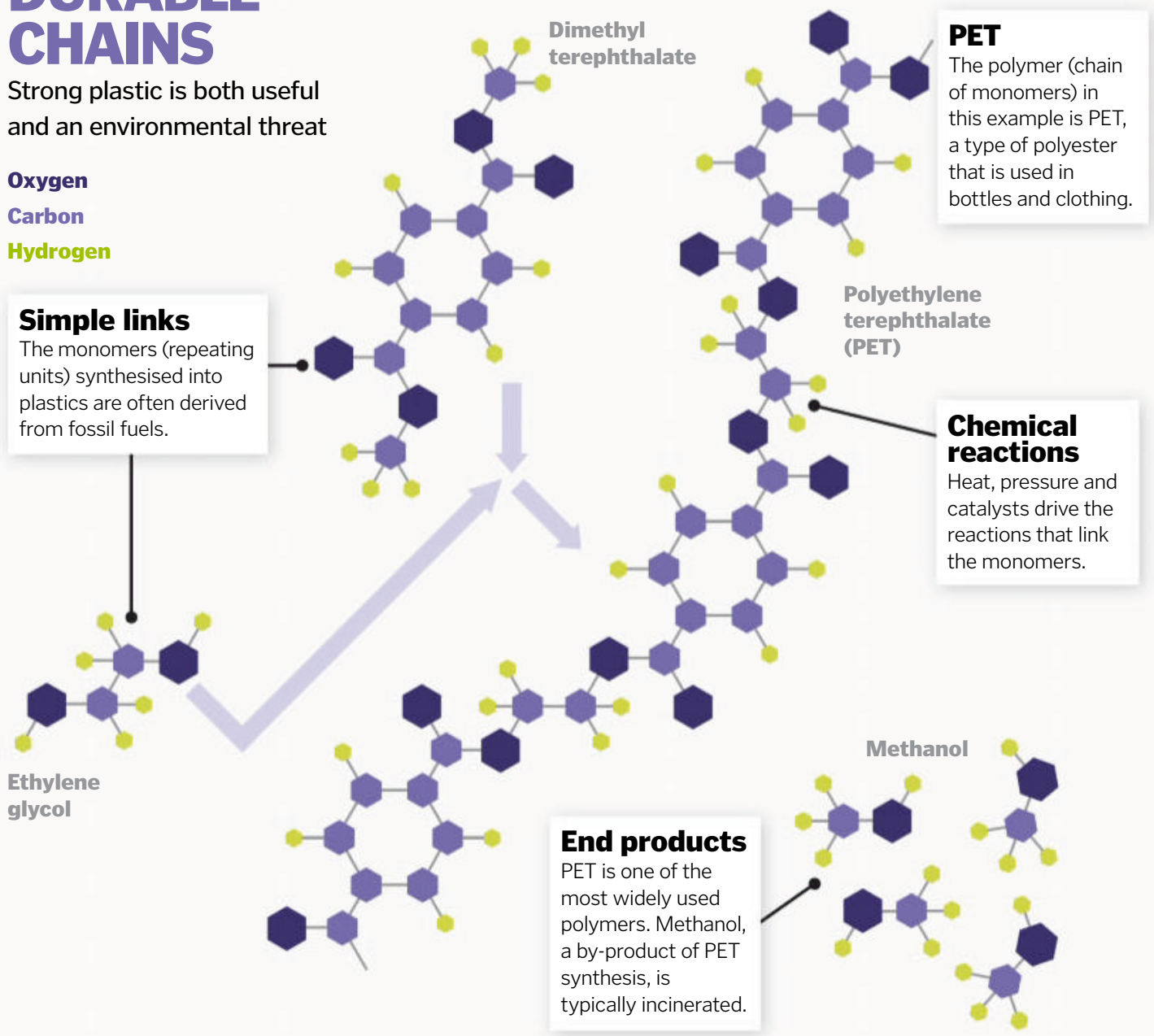
These incredible materials are cheap, clean and waterproof. They can be thick or thin, bendy or brittle, brightly coloured or completely clear. We can wear them against our skin, wrap them around our food and use them to construct everything from pens and tinsel to smartphones and spaceships. Plastics are strong enough to support buildings, light enough to fly and slippery enough to stop eggs sticking to frying pans. But these wonder materials are so cheap that we don't think twice about throwing them away.

Today, we make 300 million tons of plastic a year, half of which goes straight in the bin. We waste 1 million plastic bottles a minute, half a million plastic straws a day and 4 trillion plastic bags every year. Of all the plastic we have ever made, nearly 80 per cent is in landfill or littering the natural world. Nearly a third of plastic packaging goes straight out to sea, where it will stay for several human lifetimes; enzymes made by living things can't touch the human-made chains that make plastic so strong and durable.

> *"Making paper produces more pollution than making plastic"*

DURABLE CHAINS

Strong plastic is both useful and an environmental threat



WHAT CAN WE DO?

The Ocean Cleanup project sits at the very end of the plastic economy, mopping up the river of waste pouring out of our homes and businesses. But, as System 001 scours the sea, people across the globe are stepping up to battle the plastic production line.

The biggest plastic-producing sector is packaging. There are bags, trays and films made from low-density polyethylene (LDPE); milk and shampoo bottles made from high-density polyethylene (HDPE); water bottles and cleaning fluid bottles made from polyethylene terephthalate (PET); plates, cups and cutlery made from polystyrene; insulated packaging made from expanded polystyrene; and bottle caps, crisp packets and ice cream tubs made from polypropylene. Across the world, we use an estimated 10 million plastic bags every single minute. To stem the plastic tide, it makes sense to start here.

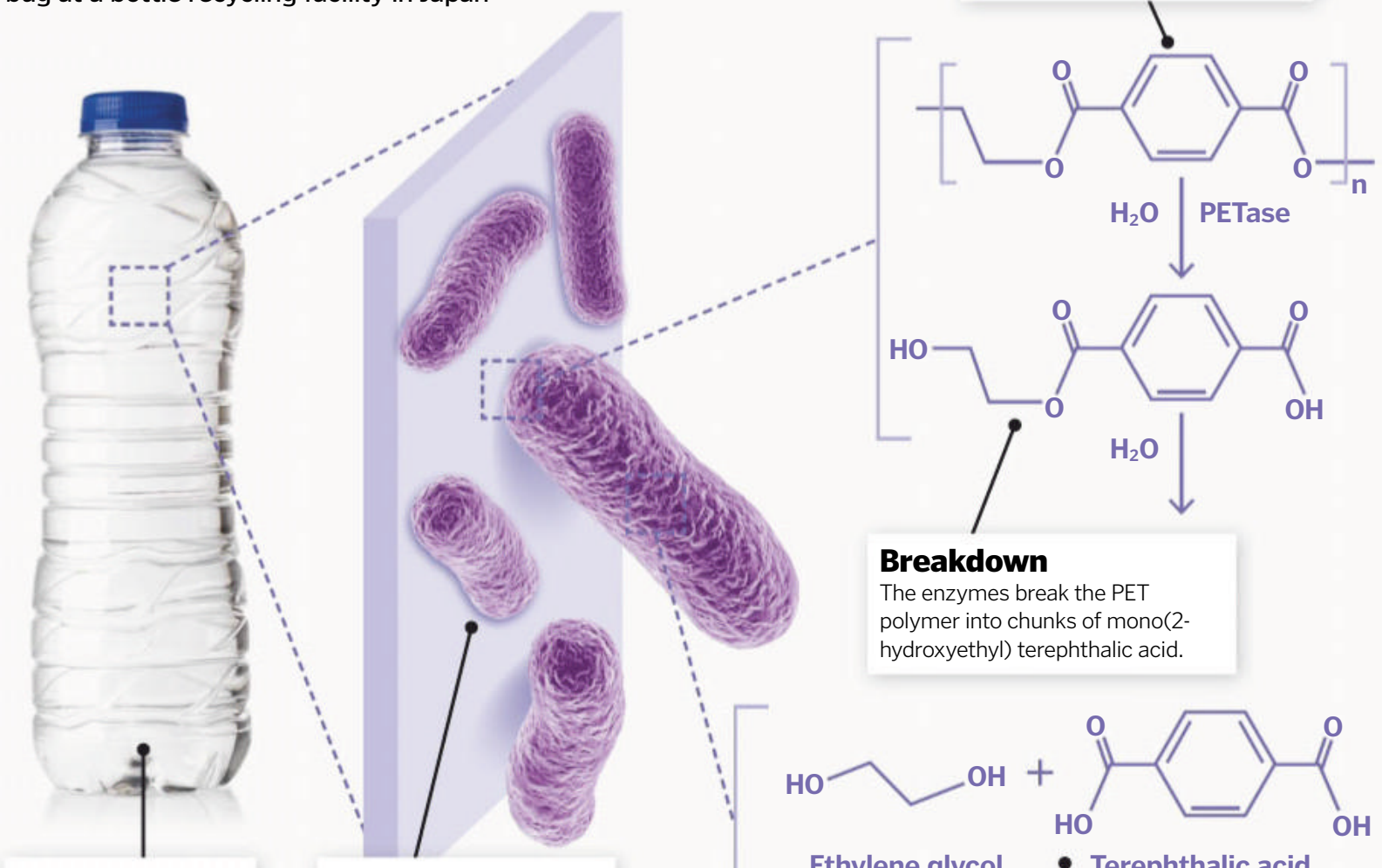
Since it launched in 2017, more than 50 countries have signed up to the UN Environment Clean Seas campaign. Single-use plastic is now firmly in the firing line, and countries across the world are phasing them out. Taiwan is ramping up to a total ban on single-use straws, cups and plastic bags, Zimbabwe plans to ban expanded plastic food packaging, and Kenya has already made plastic bags illegal; people found making, selling or using them face a fine of up to £30,000 (approximately $38,000) or up to four years in prison. They may seem drastic, but these tactics are working. In the UK, a 5p tax on single-use plastic bags has seen the number of bags used in England drop by more than 80 per cent.

Bags, straws and microbeads are some of the easiest targets; switching to non-plastic alternatives is cheap and simple. But when it comes to other single-use products like bottles, cutlery and coffee cups, the challenge is greater. One option is to replace plastics with traditional materials. We could use glass, metal, paper, card or jute (vegetable fibre). Yet, while recyclable, these materials aren't always better for the environment. Making paper produces more pollution than making plastic, and it also consumes more energy and more water. And, while glass production is more environmentally friendly, the containers themselves are heavy and bulky, racking up more pollution when products are eventually shipped out.

Creative start-ups are already experimenting with new options, including cutlery made from wheat, water bottles made from seaweed and

The bacteria that eat plastic

In 2016, scientists found a plastic-munching bug at a bottle recycling facility in Japan



PETase
The bacteria makes enzymes called PETases, which break down the plastic polymer chains.

PET
Polyethylene terephthalate (PET) is the kind of clear plastic used in drinks bottles.

Ideonella sakaiensis
Scientists discovered a species of bacteria that has evolved to use PET as food.

Breakdown
The enzymes break the PET polymer into chunks of mono(2-hydroxyethyl) terephthalic acid.

Digestion
The bacteria take up the chemical chunks and split them apart to make their own molecules.

WHAT IS PLASTIC?

Plastic polymers are long chains of molecules linked by carbon-carbon bonds.

Polymer chains contain thousands of repeating subunits called monomers.

Polymers also exist in nature, but their chemical bonds break down more easily.

Thermo-plastics melt when they get hot, reforming into new shapes.

Thermosets fix into one shape and don't melt when heated.

Chemical additives, like dyes, can slot between the polymer chains.

There are seven kinds of plastic, sorted according to their chemical similarities.

The raw ingredients for plastics are hydro-carbons from coal, gas and oil.

5 FACTS ABOUT COMPANIES MAKING CHANGES

1 Ecostrawz
Ecostrawz make reusable and single-use straws without any plastic. Their glass and metal options last for a good few years, while their bamboo and wheat versions rapidly decompose.

2 KeepCup
The makers of these reusable cups designed them with takeaway coffee in mind. With replaceable parts made from plastic, glass and silicone, they're designed to last for years, not minutes.

3 BioCellection
This California-based start-up focuses on contaminated plastic waste that's too dirty to recycle. They shred the waste, decompose the polymers and turn the plastic into chemicals that can be used for something new.

4 Recycling Technologies
This company uses heat to crack through plastic polymers. Their recycling process breaks up the long strands, turning them back into oil and gas that can then be used again.

5 Vegware
This company sell plant-based disposable packaging to cafes, restaurants and bars. When combined with food waste and sent to industrial recycling facilities Vegware becomes compost in just 12 weeks.

The challenge of recycling

Some items are harder to reycle than others

▲ Easy ▲ Manageable ▲ Difficult ▲ Very difficult

1

PET
Polyethylene terephthalate
Bottles, food jars, clothing, carpet fibre, some shampoo and mouthwash bottles.
11%
(global plastic waste, 2015)

2

HDPE
High-density polyethylene
Detergent and bleach bottles, snack boxes, milk jugs, toys, buckets, plant pots and bins.
14%

3

PVC
Polyvinyl chloride
Credit cards, window and doorframes, gutters, pipes and synthetic leather.
5%

4

LDPE
Low-density polyethylene
Packaging film, bags, bubble wrap, flexible bottles, wire and cable insulation.
20%

5

PP
Polypropylene
Bottle tops, drinking straws, lunch boxes, coolers, fabric and carpet fibres, tarps and nappies.
19%

6

PS
Polystyrene
Plastic-foam cups, egg boxes, meat trays, packing peanuts, coat hangers, yoghurt pots and insulation.
6%

7

OTHER
Nylon fabrics, baby bottles, compact discs, medical storage containers, car parts and watercooler bottles.
24%

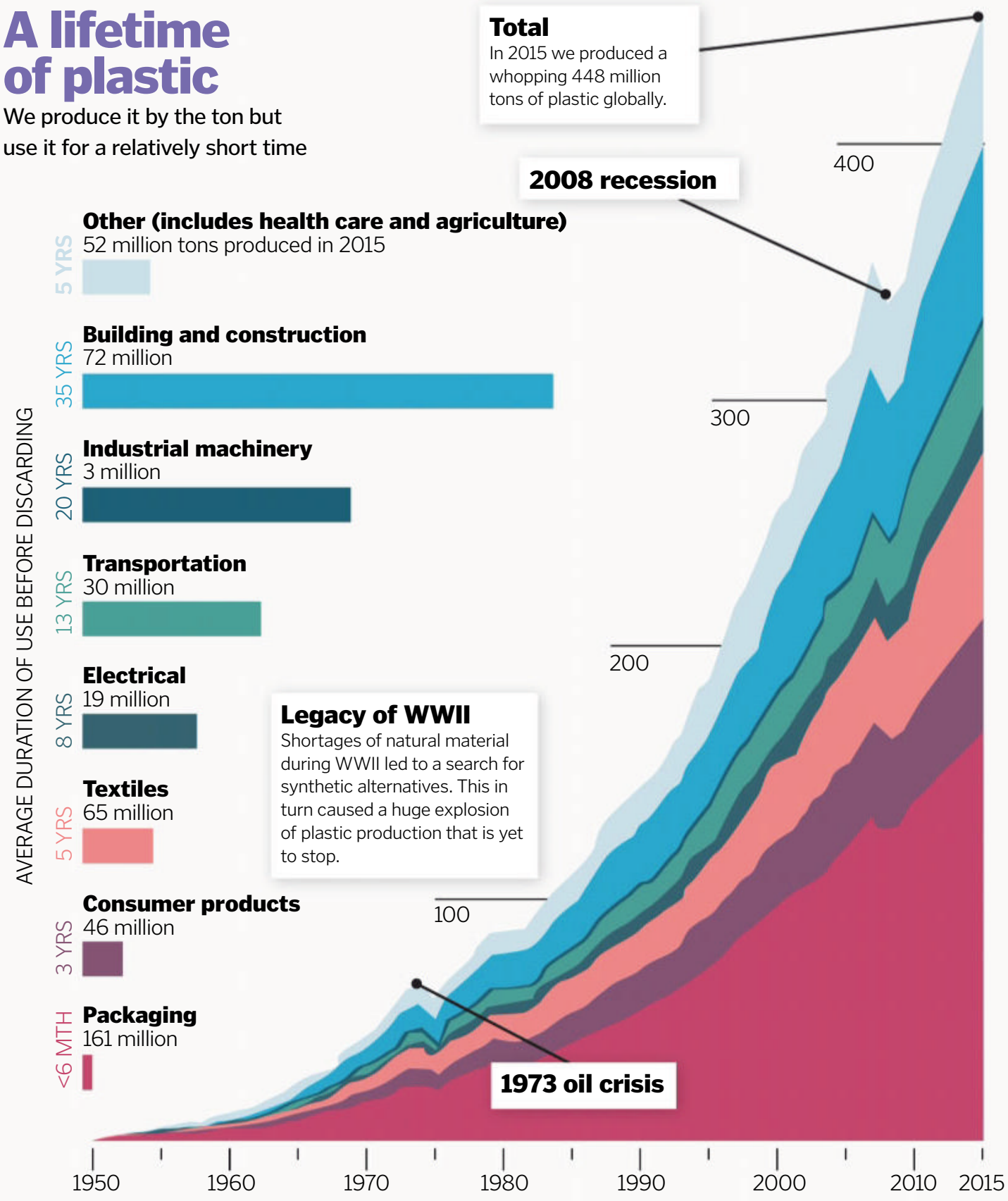
six-pack rings made from barley. Designed to disappear after you use them, they satisfy the craving for single-use solutions without polluting the planet. But knocking plastic off the top spot will take time. Until then, we need to work with what we've got.

In Japan, there are no plastic bans yet. Instead, they focus on waste management, prioritising recycling so that trash never reaches the sea. Non-recyclable plastics pass through incinerators, releasing heat that turns turbines to make electricity. This approach tries to turn our linear model of product design, consumption and waste into a more circular system. The dream would be to close the loop so that all discarded plastics become raw materials for future production. Changes to design and recycling could make products last longer, make them easier to repair and easier to repurpose at the end of their life, and changes to energy recovery methods could help us to get more out of plastics too contaminated for reuse.

This process is already underway. In Europe, a goal set in December 2017 aims to see 55 per cent of plastic packaging recycled by 2030. But there's only so much we can do in our own homes to recycle the goods we buy. To help us to achieve this goal, policy changes could start to make companies responsible for what happens to their products after we've used them. In South Africa, for example, members of the PET Recycling Company pay a levy on the raw materials for plastic production. This money then goes back into redesigning packaging and recycling post-consumer waste. Not only does this help the planet, it also creates jobs, which can be better for economies than banning plastics all together. Back in the UK, the UK Plastics Pact is working with the packaging

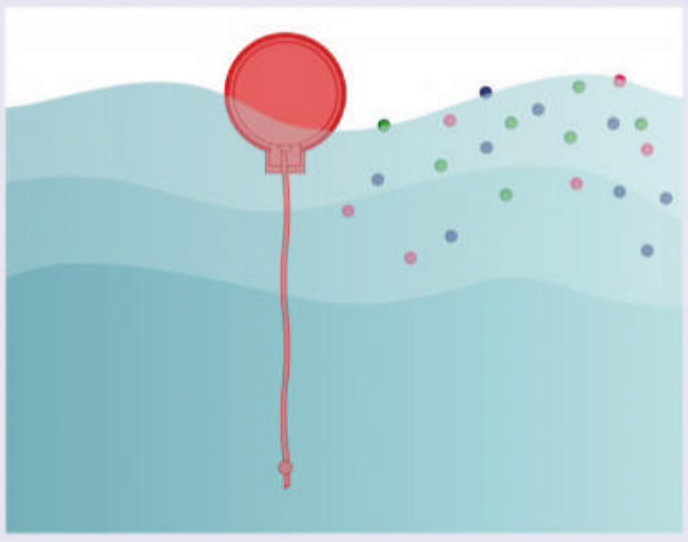
A lifetime of plastic

We produce it by the ton but use it for a relatively short time

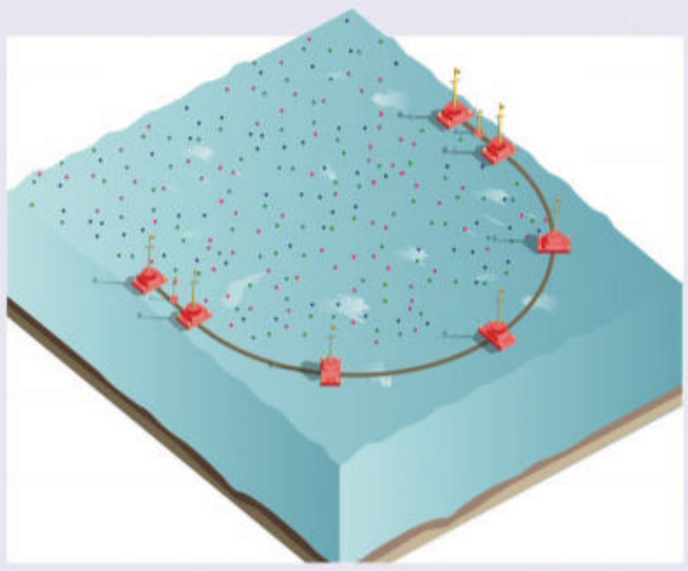


The Ocean Cleanup

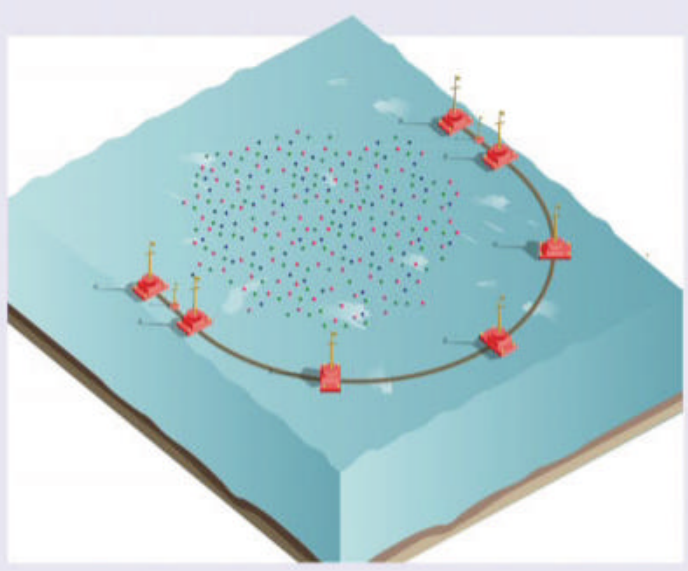
The floating nets collecting waste in the oceans



1 Chasing plastic
A three-metre skirt dangles from a 600-metre floater. Wind and waves push against the floater, moving it through the water faster than the plastic, which floats in the current.



2 Corralling the plastic
Plastic particles cannot get over the floater or under the skirt. As the wind and waves move the structure through the water the plastic becomes trapped inside.



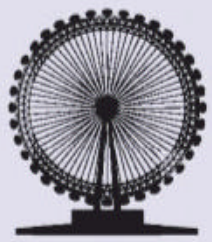
3 Build up
Pressure on the skirt from the current bends the system into a U-shaped trap, preventing plastic from escaping. It moves with the wind, tracking the plastic through the water.

How much plastic do we produce?

1950	2017	2050
2M	**8.3B**	**34B**
METRIC TONS	METRIC TONS	PROJECTED METRIC TONS

How heavy is 8.3 billion metric tons?

160,985 x Sydney Harbour Bridge
58,200 metric tons



4 million x London Eye
2,100 metric tons

75 million x Dreamliner
110 metric tons

1 billion x Elephant
7.5 metric tons

Recycling helps to create a circular economy, feeding waste back into production

sector to transition to reusable, recyclable or compostable plastics. They also want to bring plastic recycling to 70 per cent by 2025.

Scientists are experimenting with biodegradable plastics, like polylactide (PLA). It's made from lactic acid, which comes from corn, and it takes just 12 months to break down. For plastics that we can't recycle, new methods hope to capture more energy from waste by turning them into fuels. A process called gasification heats plastics with air to make a gas that can be burnt. Another, called pyrolysis, heats them without air to make a liquid fuel like oil.

There are still problems to iron out with these new technologies. Burning plastic waste can be hazardous, and to make enough biodegradable plastics to replace the real thing we would need to turn over vast areas of land to corn monocultures. Then there is the fact that even though biodegradable plastics can break down, it doesn't mean that they will. They need to reach temperatures over 50 degrees Celsius, which is achievable inside industrial composters, but not when plastics escape into the ocean. But we're moving in the right direction, and we all have a part to play.

We as individuals can choose alternatives to plastics and put pressure on governments and brands to make bigger changes. If we focus on reduction, reuse and recycling, we could close the loop in the plastic economy and stop this incredible material leaking out into the sea.

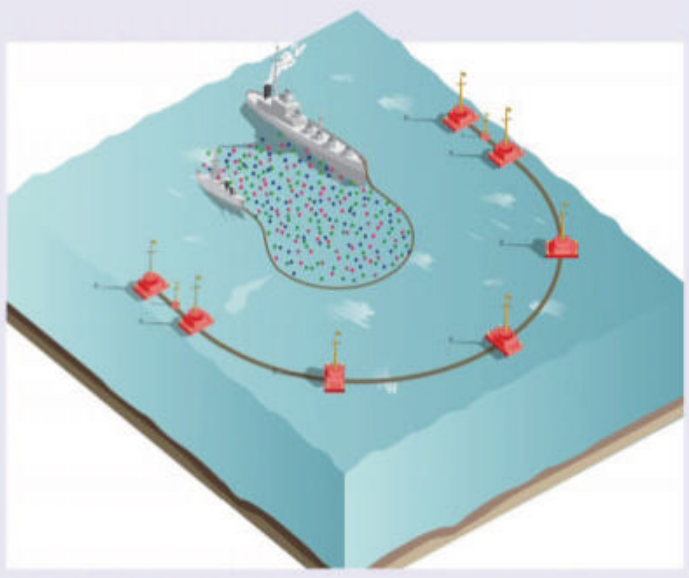
Why won't plastic biodegrade?

Microbes quickly get to work on organic waste, like paper and vegetable peelings, but they can't get to grips with plastic. This might seem odd, as we make plastic from oil, which comes from the remains of ancient plants and animals, but it's all down to the way plastic is made.

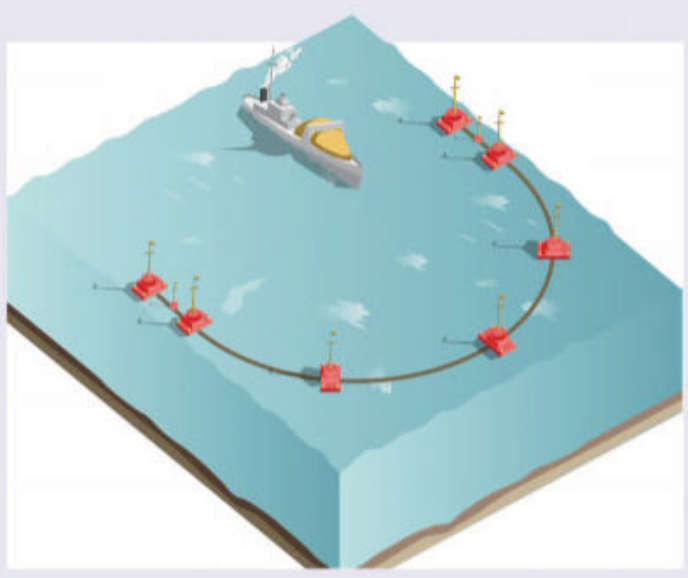
Natural polymers use chemical links called peptide bonds, while plastic polymers contain carbon-carbon bonds. These bonds are much stronger, and that's both a gift and a curse. Most of the enzymes living things use to break organic molecules down can't manage to break these links. This helps to make plastics so durable, but it also makes them hard to get rid of.

There are only a handful of organisms, including some fungi and bacteria, capable of breaking them down. Scientists are still working out how best to use them. Ironically, if more organisms learn this trick, it could put the durability of vital plastic structures under threat.

Approximately 2.1 billion tons of waste is dumped globally every year



4 Clean up
The system sends signals to satellites overhead, keeping operators updated about its status. As plastic starts to build up, support vessels come in to gather the waste.



5 Recycling
The collected plastic returns to shore for proper disposal. Meanwhile, the system continues to move through the water collecting even more waste.

WHAT CA

How long does waste take to break down?

1 month
For a paper bag to decompose

2 months
To get rid of a cardboard box

1 million years
For an aluminium can to break apart

2 years
To compost an orange peel

12 years
For a cigarette butt to disintegrate

20 years
Until a plastic bag breaks apart

450 years
For a plastic bottle to fall to bits

SAY NO TO SINGLE-USE CUTLERY

We only use plastic cutlery for a few minutes before we throw it away, so minimise your plastic footprint by refusing disposable knives, forks and straws. Pop a normal fork in your bag for lunch on the go and invest in a washable metal straw if you can't go without. If you find yourself caught out, look for outlets offering biodegradable or edible cutlery.

CARRY A REUSABLE CUP AND WATER BOTTLE WITH YOU

According to the World Wildlife Fund, people in the UK throw away more than 7 million coffee cups every day. Invest in a reusable cup and bottle and ditch the disposables. Many coffee outlets offer a discount if you bring your own cup, and you can find free places to refill your water bottle using the app Refill.

TRY ZERO-WASTE SHOPPING

Rather than picking a pre-filled plastic bag from a shelf, try bringing your own bags and opting for loose fruit, vegetables and bread. Some 'zero-waste' supermarkets also allow you to buy loose dried foods like oats, nuts, tea, spices and crisps. Even if you don't live near one, you can still save on plastic by saying no to products with excessive wrappers. Opt instead for store cupboard staples with metal, glass or cardboard packaging.

DID YOU KNOW? *Recycled plastic can go on to become bottles, benches, bins, jackets, insulation and even car batteries*

AN YOU DO?

SWAP LIQUIDS FOR BARS AND POWDERS

Laundry detergent, hand soap, shampoo and other cleaning products contain a lot of water, and because they're wet we need to store them in plastic. Adding the water yourself at home can save a mountain of packaging. Where possible, switch to dry versions packed in paper or card, like solid soap and laundry powder. When you do need to buy liquids look for concentrated versions and dilute them down at home.

INVEST IN REUSABLE BAGS AND BOXES

Ditch cling-film, freezer bags and foam takeaway packets and invest in a set of reusable bags and boxes for your lunch and leftovers. Hard, recyclable plastic boxes last much longer than their disposable counterparts and can be stored in the fridge or freezer and put in a microwave. Or, if you'd prefer to be completely plastic free, you could opt for glass, metal or dishwasher-safe silicone.

SWITCH TO REUSABLE NAPPIES

Reusable nappies have come a long way since bulky terry towelling. No longer pinned together, they now offer poppers and velcro and there are no fancy folds to learn; they go on just like disposables. They have three parts: a waterproof wrap on the outside, an absorbent nappy in the middle, and a biodegradable or washable liner next to the skin. Pre-rinse cold in the washing machine and then run a long, warm wash to get them clean. Not only do they prevent nappies going to landfill, but they work out cheaper, even with all the washing.

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THE FUTURE OF MEDICINE

Electroceu

Should we ditch drugs to make way for an electrical alternative?

Words by **Scott Dutfield**

...U KNOW? *In the future, electroceutical implant devices could be less than 100 nanometres wide [as small as a virus]*

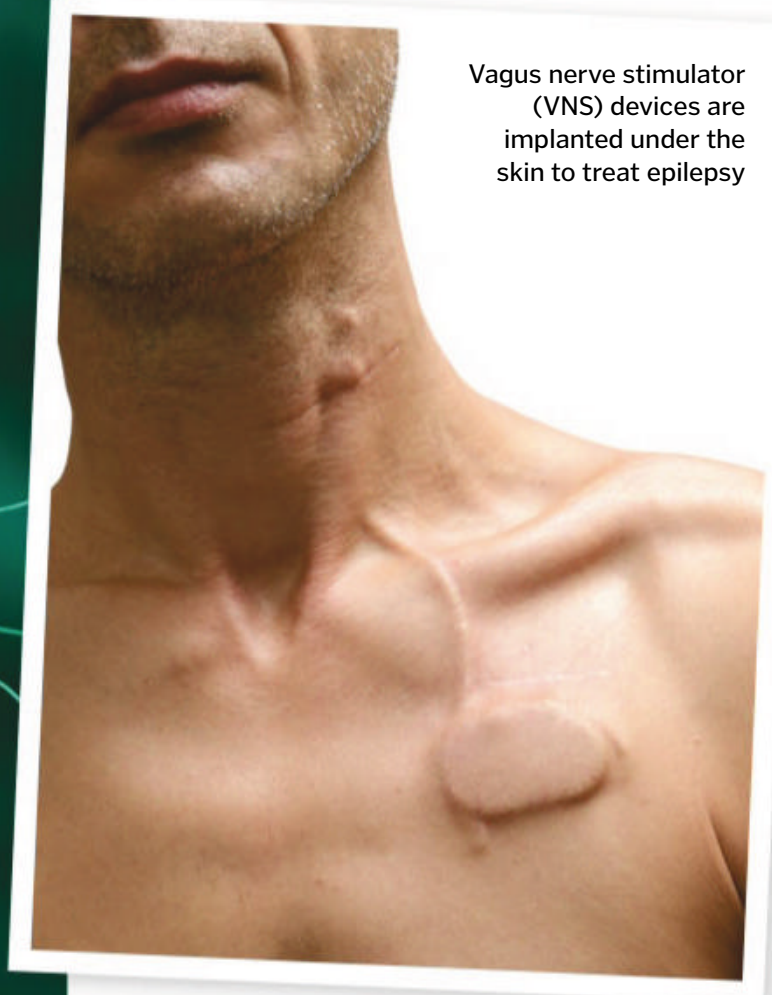
...tical...s

A great many of us often don't think twice about popping a pill to treat a chronic condition. The most up-to-date data from the European Union suggests around 49 per cent of people within its 28-member countries aged 15 and over use prescribed medicines. However, with the introduction and development of bioelectronic technologies, pills could soon be a thing of the past for some conditions.

Implanted electrical devices that work to repair, replace or restore parts of our bodies have been employed by doctors since the 1950s. The first cardiac pacemaker was implanted in a 43-year-old male back in 1958 to combat his cardiac arrhythmia. Since then devices have been created to restore senses such as hearing and sight and regulate insulin for those suffering from diabetes. However, in recent years 'electroceutical' devices have been making waves as a treatment for chronic conditions.

Fundamentally, the principle of electroceuticals is to emit a low-energy electrical pulse to stimulate different nerves in the body to aid the reduction of symptoms for an array of physical conditions such as epilepsy and rheumatoid arthritis. Recent investigations into externally worn devices have even suggested that they might be a treatment solution for mental health conditions such as depression and anxiety, an incredibly exciting possibility.

One of the biggest downfalls of chemical medication are the potential side-effects they can cause. These side-effects mostly occur due to pharmaceuticals affecting not only the intended target but several organs when they enter the body. Electroceutical treatments offer a more accurate approach as they can focus on



Vagus nerve stimulator (VNS) devices are implanted under the skin to treat epilepsy

particular nerves connected to specific organs, limiting the number of side-effects. For example, one of the most widespread uses of electroceuticals is treating epilepsy with a vagus nerve stimulation (VNS) device. Epilepsy is a condition whereby nerves 'fire off' abnormally when sending signals to different parts of the body, resulting in seizures of varying degrees. The condition affects more than 500,000 people in the UK alone. VNS devices are able to help manage these symptoms through artificial electrical stimulation.

Implanted beneath the skin and hooked onto the vagus nerve at the neck, a generator, which resembles that of a pacemaker, creates electrical pulses that feed through a lead to the nerve at regular intervals. This stimulation regulates the electrical signals through the vagus nerve into the brain, reducing seizures. Should a seizure occur, or even a warning of an oncoming episode, a handheld magnet can be waved over the implant's generator to produce more impulses, preventing or reducing its longevity.

These VNS devices are not a cure for a condition, but they greatly relieve the symptoms. The same technology has also been used to treat those with rheumatoid arthritis, a long-term autoimmune disease that causes inflammation at the joints. A VNS device can send electrical impulses along the splenic nerve to stimulate the spleen, thereby reducing its immune response and any inflammation.

The potential for electroceuticals to become commonplace treatments is vast, but finding the right nerve circuitry can be a tricky task. There are 12 pairs of cranial nerves and around 86 billion neurons in the brain alone, each delivering electrical messages through nerves around the body.

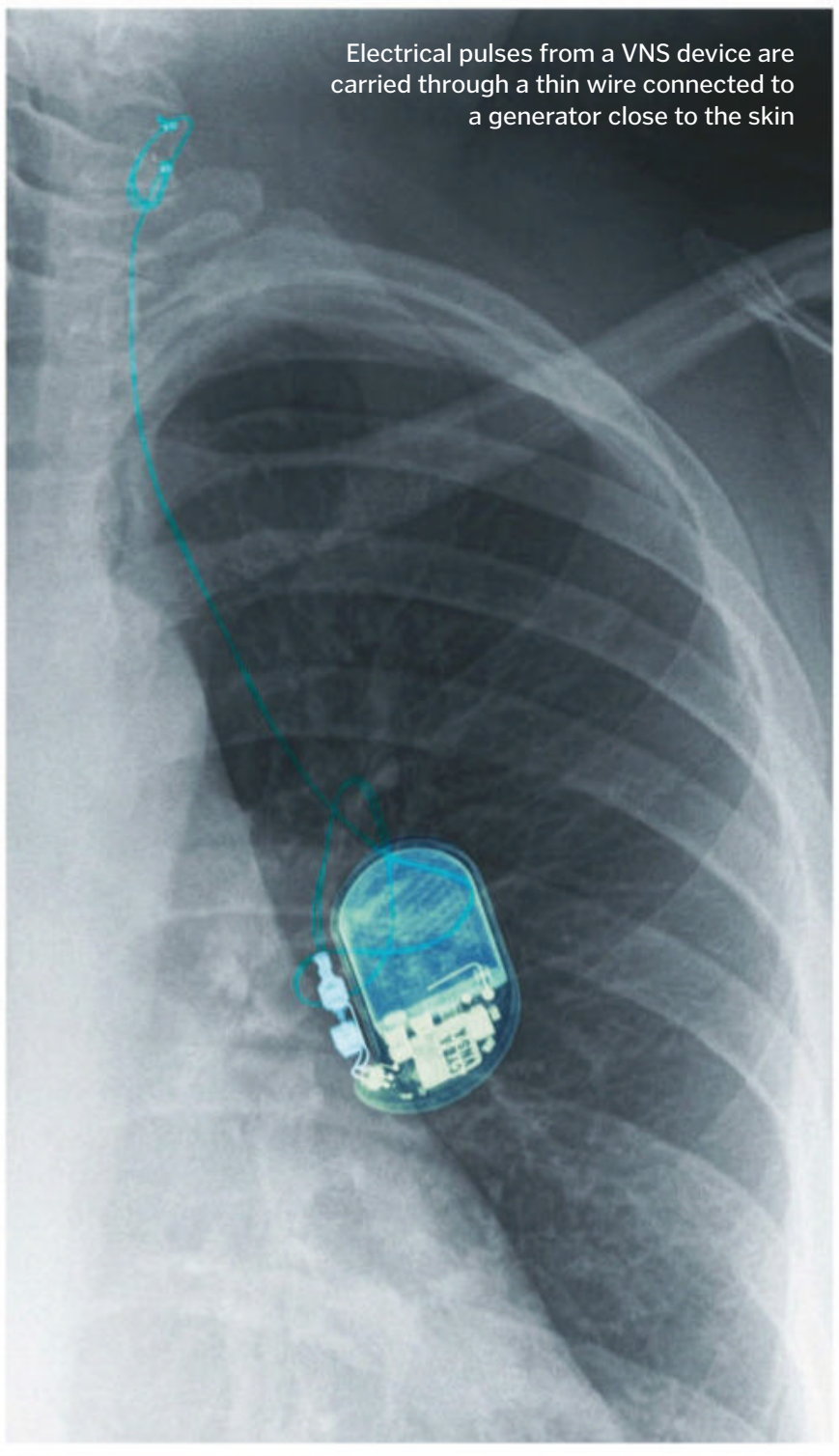
In order to use nerves as a method of treatment, scientists must first locate which nerve carries which message and to where around the body. Brain mapping is a way of creating a road map of the mind to reveal all the avenues through the body. There are several methods currently used to map the brain, one of which is electromyography, which measures the electrical activity in the brain through electrodes placed around the head. However, each of our brains is wired differently, with the exception of major nerves such as the vagus nerve. Therefore it is difficult to create universal electroceuticals, and thus far a complete map of the brain's complex network of neurons is yet to be visualised.

"Electroceutical devices have been making waves as a treatment for chronic conditions"

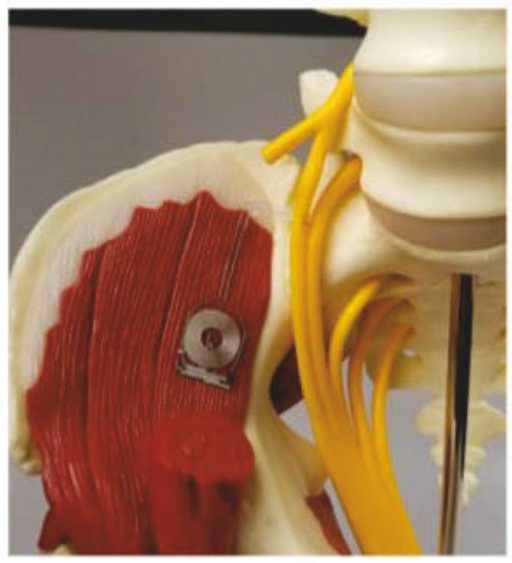
Though VNS devices seem to hold the monopoly on bioelectronics, recent discoveries are shedding light on the potential for electroceuticals to repair physical damage within the body too. Earlier this year researchers at the Northwestern University and the University of Washington, US, created an implantable wireless device that speeds up the regeneration of damaged nerves.

The device (trialled on rats) emits regular pulses of electricity to damaged sciatic nerves to accelerate nerve growth and enhance muscle control and recovery. Consisting of a thin disc that wraps around nerves, the stimulator is activated wirelessly by a transmitter outside the body. This technology is designed to only work for a specific amount of time during the healing process. Engineers use materials that allow it to biodegrade and be absorbed into the body, preventing another extraction surgery.

Of course, electroceuticals are not the answer to all of our medical problems; bacterial diseases, for example, cannot be treated using these electrifying methods. Electroceutical technology is still in its medical infancy in terms of its general use, and its long-term effects have yet to be determined.



Electrical pulses from a VNS device are carried through a thin wire connected to a generator close to the skin



New devices built to repair nerves will dissolve once the healing is completed

Electromyography uses electrodes to map the brain's neural pathways

Wearable tech

Meet the man behind Modius – the electro-stimulation headset that tricks the brain into thinking you're working out

Dr Jason McKeown is the CEO and co-founder of Modius Health. Here he explains the science behind their new headset and what the future may hold for wearable electronic medicine.

How does Modius stimulate weight loss?
The hypothalamus controls all elements of metabolism, so that's your metabolic rate, core temperature, your appetite even and all of your hormone profile. Your vestibular nerve connects to that, so we used electricity to stimulate the nerve, similar to the way implants do. We believe that your vestibular nerve picks up physical activity, so it's almost a reference point to how active you are. Say you're a bear hibernating; there is zero physical activity, so your vestibular input is zero because you're just lying there, sleeping. So the metabolism shifts slightly to store fat. It's a very old evolutionary thing that guides metabolism to how physically active we are. So basically, we kind of hack that connection to some degree and activate it over and over again using electrical stimulation, and that's how we developed this headset that you can wear for an hour to repeatedly stimulate that part of the brain.

Why doesn't this form of stimulation affect other brain functions?
The vestibular nerve itself only has projections into the areas [of the hypothalamus] that physical activity has any reference to. It's almost like a filter that works by filtering areas that are only relevant for things that connect with physical activity.

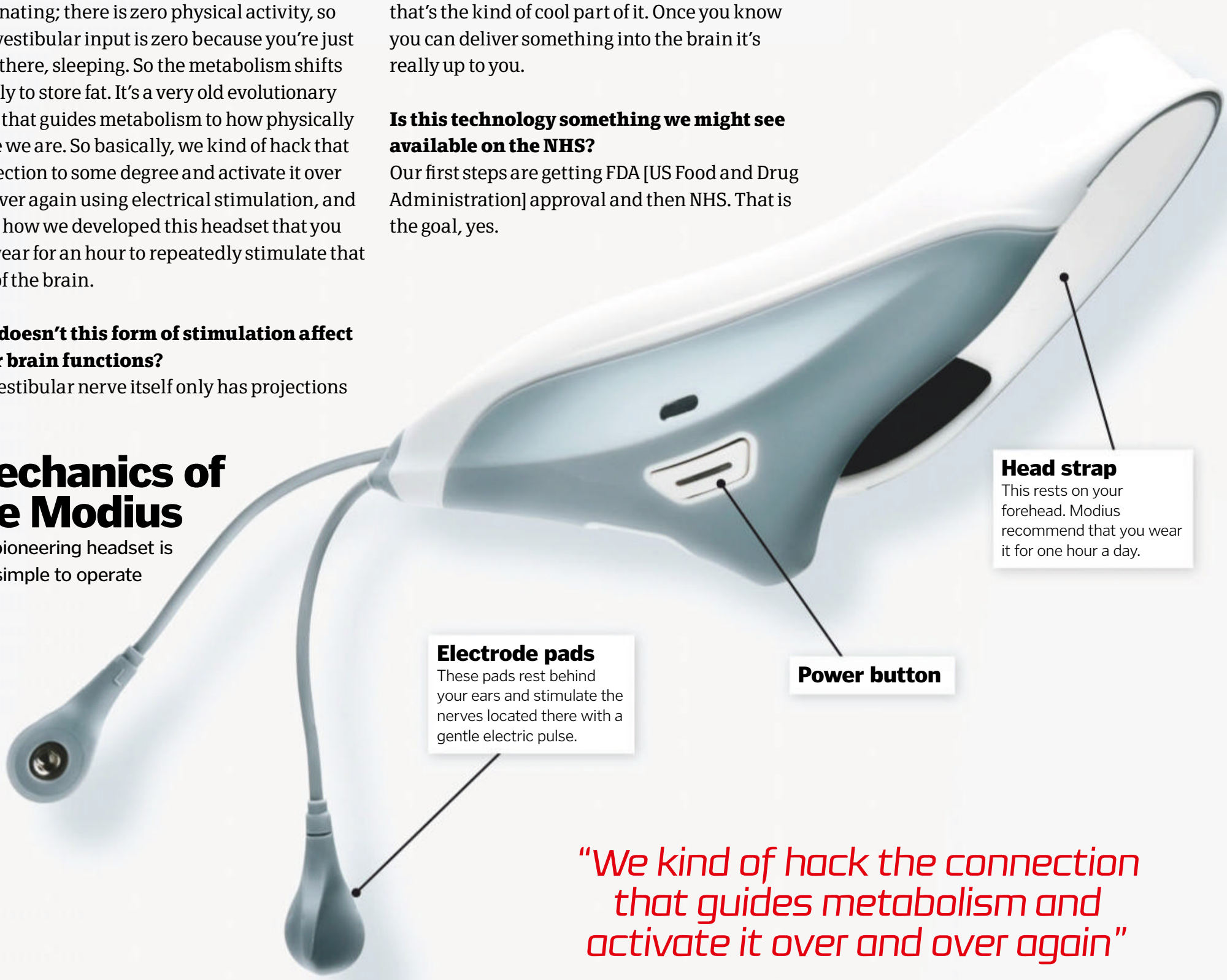
What is the future of Modius Health and wearable bioelectronics?
What we can do isn't limited to weight loss. That just happened to be the first thing we looked at. So we are actually looking in the mental health space, at anxiety and depression also. We have also started trials in migraines and epilepsy. People think we are just a weight loss company, but the technology is actually a delivery method. It delivers stuff to the deep part of the brain, that's the kind of cool part of it. Once you know you can deliver something into the brain it's really up to you.

Is this technology something we might see available on the NHS?
Our first steps are getting FDA [US Food and Drug Administration] approval and then NHS. That is the goal, yes.

Dr McKeown founded the Belfast-based company Modius Health in 2013

Mechanics of the Modius

This pioneering headset is very simple to operate



Head strap
This rests on your forehead. Modius recommend that you wear it for one hour a day.

Power button

Electrode pads
These pads rest behind your ears and stimulate the nerves located there with a gentle electric pulse.

"We kind of hack the connection that guides metabolism and activate it over and over again"

Inside the new iPad Pro

Take a look at Apple's new curved-corner wonder

The big feature of this year's iPad isn't better sound, a new design or a faster processor. It has all those things, of course, but this year it's all about the screen. Apple has developed a screen technology that means LED displays can now curve around corners, rather than having to turn at 90 degrees. For the first time the iPad's screen isn't a rectangle, and that's helped Apple push it closer to the edge of the glass. The result is a beautiful image that goes closer to the edge of the tablet.

Elsewhere, the new iPad has more speakers for proper stereo sound (ideal when you're watching Netflix), as well as a Face ID system that lets you unlock your device just by looking at it. And thanks to that powerful new processor the iPad can run more robust new apps like Photoshop CC and lets you multitask using two apps at once. There's a new Apple Pencil too, which means you can draw or write on the screen just like a piece of paper – only this piece of paper is infinitely more powerful.

Then there's the USB-C port. This new port is the same one you'll find on the latest computers, which means the new iPad can connect to more devices, like cameras and displays, without the need for dongles. It can even charge your phone. It's faster to charge too, and the battery lasts for a whopping ten hours. But how did they fit all this into the thinnest iPad ever? Let's look inside to find out.

Speakers
There's a woofer and speaker pair in each corner of the iPad, so you get great stereo sound from every angle.

"The new iPad can run powerful new apps like Photoshop CC"

Display chips
The touch screen requires some clever chips to register the taps and swipes – they're tucked along the side here.

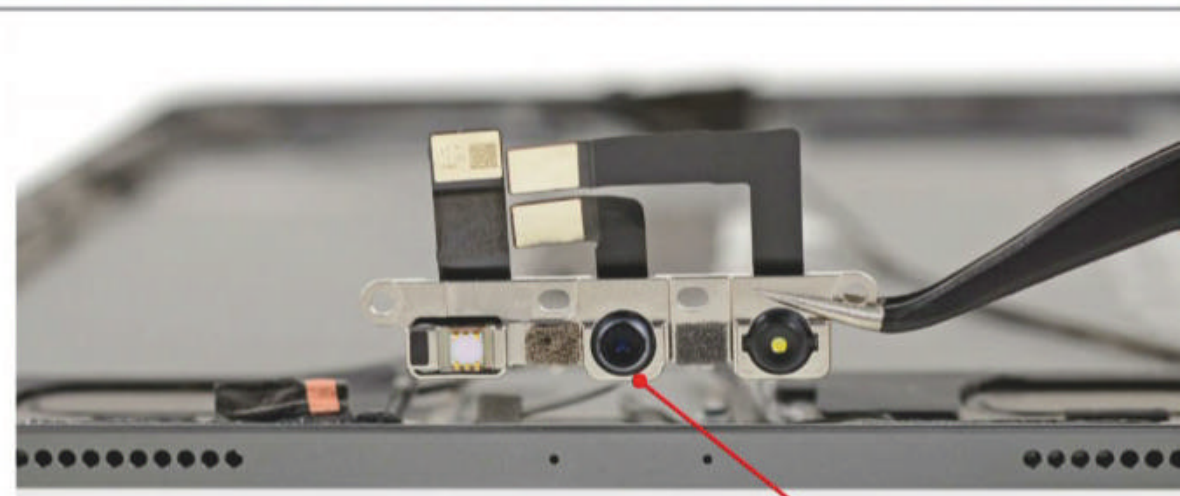
See inside the iPad Pro

Find out how all that tech fits into a tiny tablet

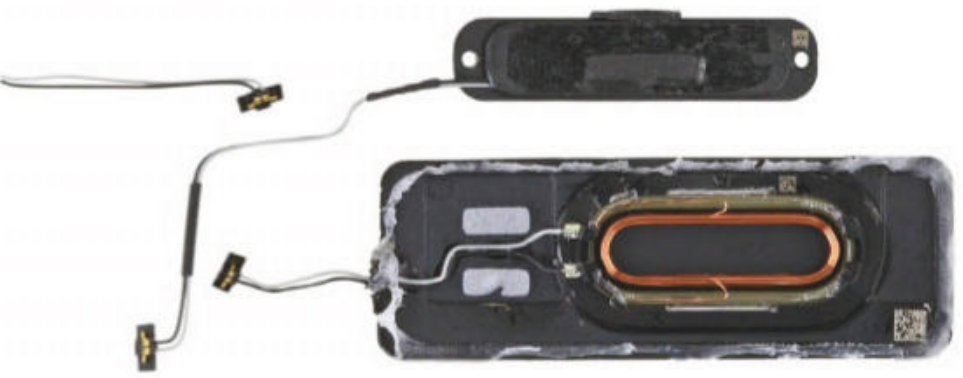
Liquid Retina display
This display uses the same technology as the iPhone XR. Apple tuned individual pixels to create the curved corners.

Battery
The 29.45Wh battery powers the iPad and takes up most of the space inside the casing. It'll last for around ten hours.

DID YOU KNOW? *With the new FaceTime app on iPad Pro you can talk to up to 32 friends at the same time*

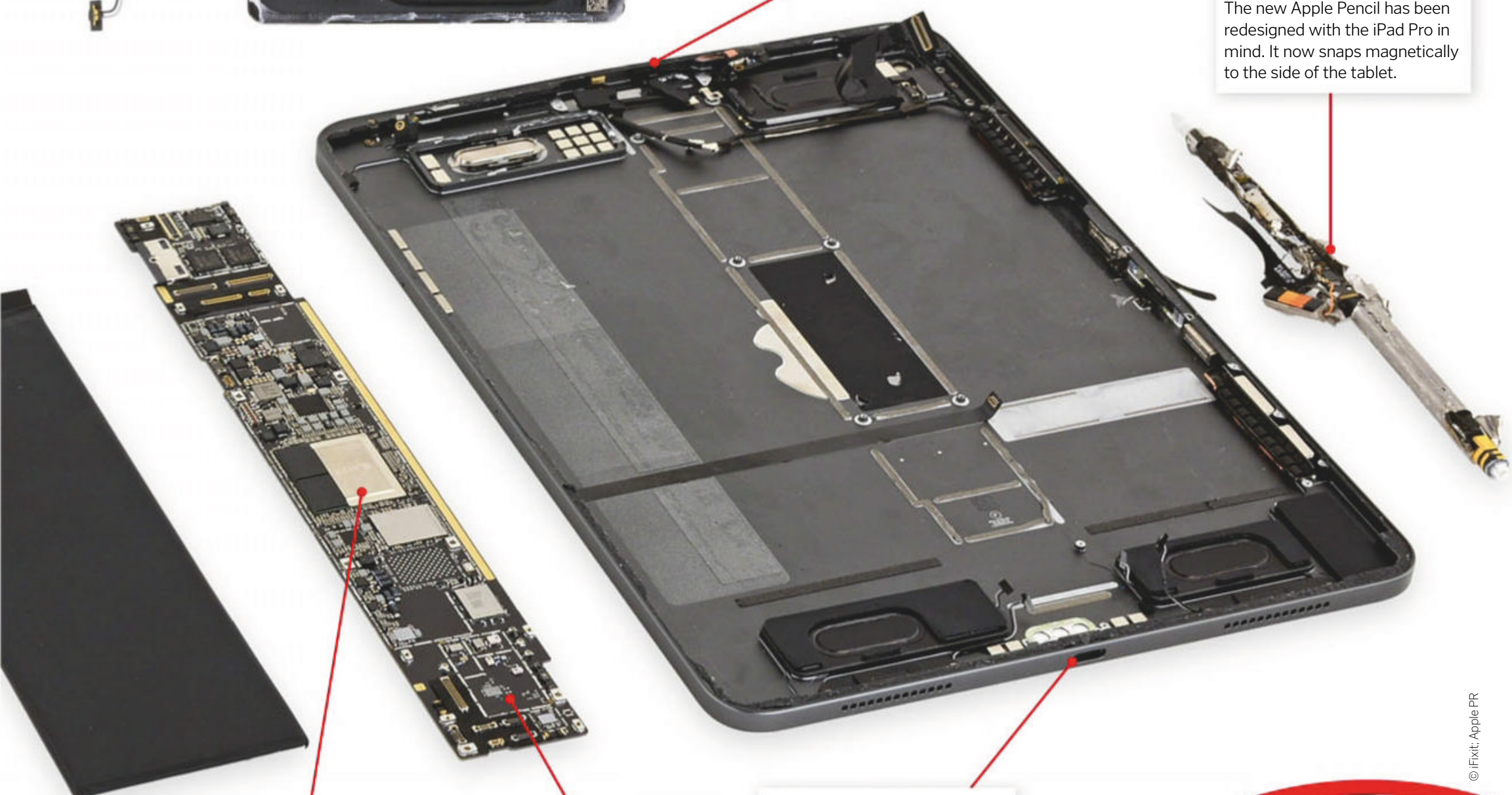


Cameras
The camera system includes all the sensors for Face ID and a seven-megapixel selfie camera.



Face ID
The camera system on the front of the iPad can scan your face, so you can unlock it and pay with Apple Pay simply using what nature gave you.

Apple Pencil
The new Apple Pencil has been redesigned with the iPad Pro in mind. It now snaps magnetically to the side of the tablet.



A12X chip
The A12X Bionic chip powers the apps that run on the new iPad, and it can run more simultaneous operations than ever before.

AR chips
The logic board also houses clever chips that make it possible to use augmented reality apps, mixing the real world with the digital one.

USB-C
The new charging port also acts as a connector for other kinds of devices, so it's now easier to use a second display with your iPad or connect a camera.

The new Apple Pencil

The Apple Pencil has been redesigned to work with the new iPad. Double tapping on the pencil will quickly switch the type of brush you're using in drawing apps, making it faster to work when creativity strikes. Pairing and charging the new Apple Pencil is simpler too – just snap it onto the side of the iPad Pro.

The Apple Pencil was already a fantastic way to get creative, but these smart upgrades make things even better. The downside? Old Apple Pencils don't work with the new iPad, and the new Pencil won't work with old iPads, so you'll have to upgrade everything if you want to use it. Classic Apple!

Q&A How to talk to your home

We speak to a pioneer of connected home technology

Elvin Nagamootoo joined British Gas, a subsidiary of Centrica, as a technical engineer in 2004. Today, he heads one of the product areas in Hive with a focus on research and development.

Hive is at the forefront of developing products to connect the home. What are some of the products available?
We have a full range of products all controllable from our award-winning Hive app, including thermostats, leak sensors, smart plugs (which you can set to switch on and off whenever you want), sensors for doors and windows, a comprehensive lighting range and internal and external cameras.

Hive has teamed up with other partners to develop the ecosystem further. What can you offer with these collaborations?
We are always working closely with other companies. They can help us in many ways, for example, we teamed up with Worcester Bosch to provide advanced diagnostics of boiler faults, helping us to help customers diagnose a fault even if they aren't aware of it. That's just one example. We integrate with other third parties including Amazon Alexa, IFTTT and Google.

The IFTTT ('if this then that') feature sounds interesting. What does it do?
This is cool because IFTTT is a platform that enables 'things' from different brands to work with each other so that customers can automate their homes. To compliment the IFTTT integration we also have Hive Actions within our app, which users can tailor so Hive devices work together to meet their needs. An example of Hive Actions is our smart lights, which can track the time of sundown, turn lighting on at the time when you need them, rather than having to adjust the schedule as the sunset time shifts.

How does all this tech communicate?
All of the Hub-based devices, including thermostats, motion door and window sensors, plugs and lighting, communicate using the Zigbee protocol – a wireless mesh network standard. It allows devices on the network to securely communicate like an expanding layer, providing a stepping stone for devices on the outer extremities of the network. Things like window sensors, which can't talk with the hub directly, can communicate via other devices.

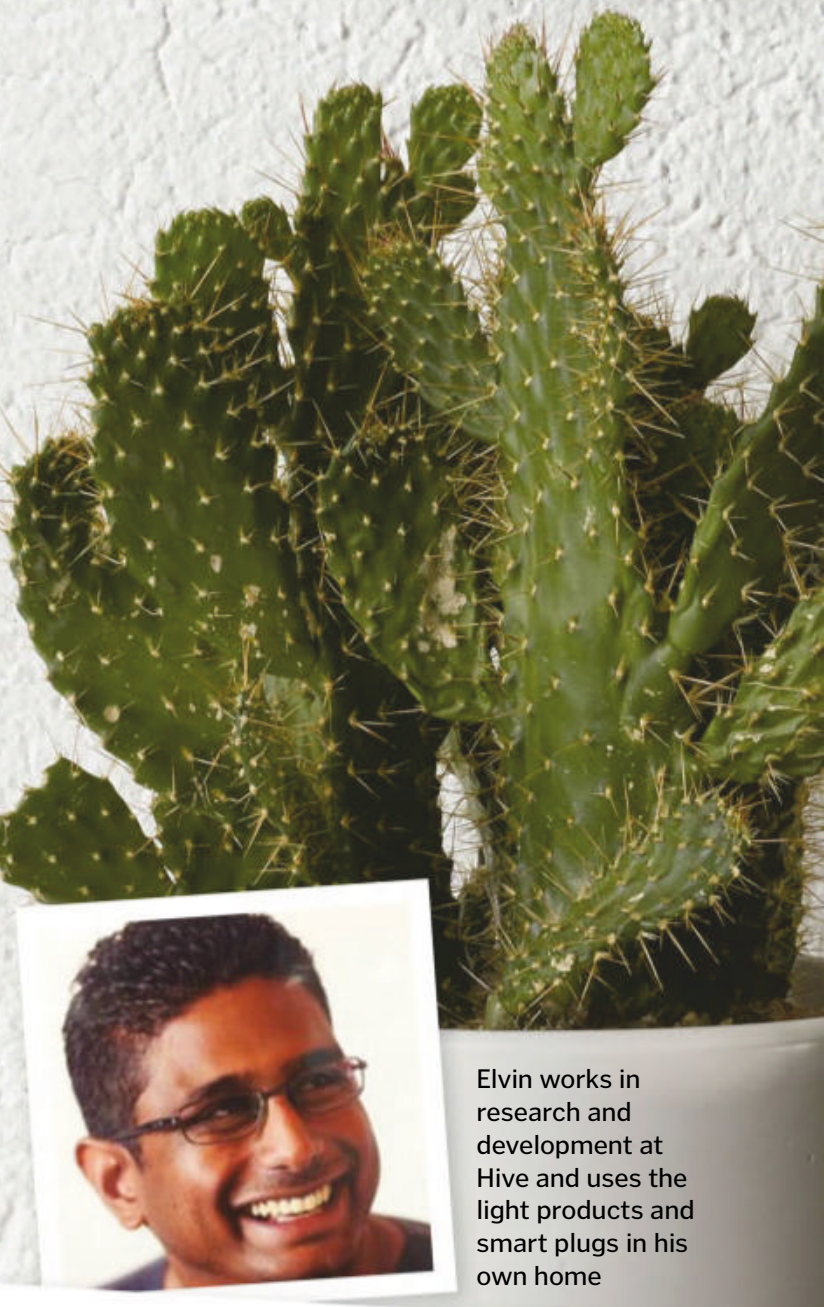
The first product (launched in September 2013) was the Hive Active Heating Thermostat. What is the most recent product to get on the market?
We have just launched our Hive View Outdoor camera, which is powered by cutting-edge technology. It is weatherproof and equipped with automatic night vision. It works 24/7 to detect sound, motion or people and sends notifications once recording starts.

With these pieces of tech communicating, monitoring the environment and sending information to consumers' smartphones, what sort of problems can Hive fix?
A lot, mostly things surrounding safety and peace of mind, but also just making life easier. There are so many examples. You know that uncomfortable feeling when you think you've left the iron on? Hive fixes that by enabling you to check in the Hive app to see if you have, and if you have left it on you can switch it off wherever you are. Hive Leak monitors water flow, so wherever you are you can be notified of a small leak before it becomes a big problem. And the Hive Hub 360 is great - it can detect specific acoustic signatures like a dog's bark or a window breaking and sends you a notification.

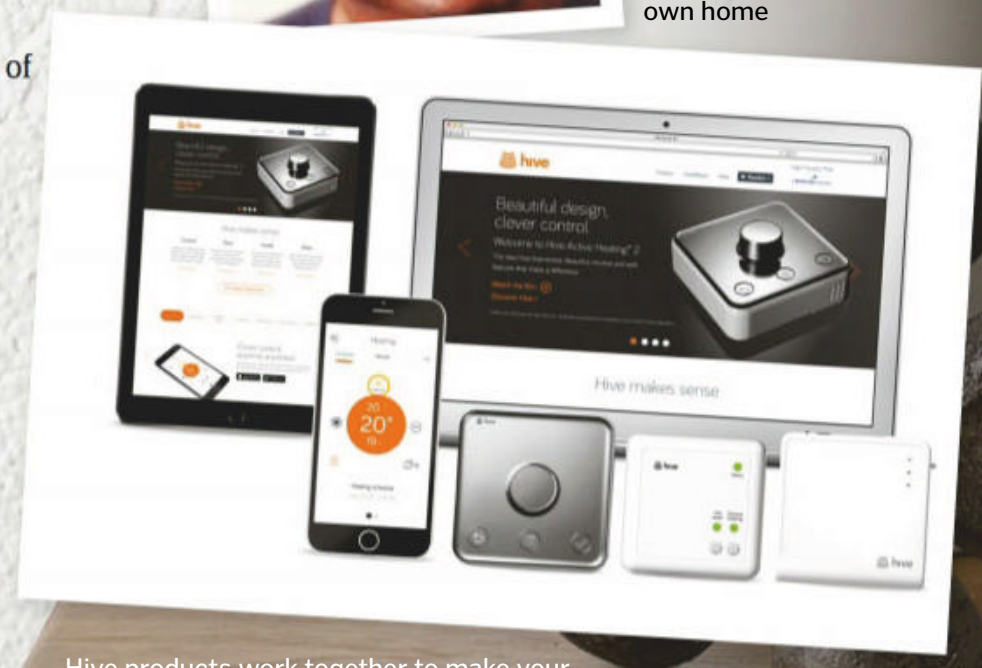
You've talked about different modes you can set. Can you give some examples?
It's so customisable. So if you go on holiday, Holiday Mode can reduce energy bills but still keep it warm enough to protect from frost. Also, with Quick Actions, instead of spending time making sure your thermostat is down and your lights are off, with just one tap you can do it all.

Where does Hive go next?
We are exploring ways that we can use smart technology to help people live independently for longer in their own homes. With a globally ageing population we see a role for connected home technology to provide peace of mind for both loved ones being cared for as well as the increasing number of people providing casual care.

A simple interface hides a device brimming with connective home tech



Elvin works in research and development at Hive and uses the light products and smart plugs in his own home



Hive products work together to make your home feel safer, cosier and more connected

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The robot pharmacist

The future of healthcare could see automation come to the forefront

The National Health Service in England treats over 1.4 million patients every 24 hours, so for doctors and nurses time is precious. Any way to make a process more efficient and less time consuming not only makes medical professionals' work easier but could save someone's life.

Automation in healthcare is on the rise and providing the much-needed assistance that medical professionals require. Innovations such as automated robotic pharmacies can lend a helping hand to improve healthcare. Robotic pharmacies as a concept vary in their level of automation, from simply acting as a smart shelf or commonly seen vending machine-style dispensary to a high-tech sorting machine able to recognise and prioritise medicine for optimal efficiency. Their common goal is to act as a librarian of medicine.

At the more advanced end of the robotic spectrum, room-filling machines equipped with smart 'box picking' robotic arms can catalogue, store, dispense and refill their own shelves. Barcodes associated with each medicine are scanned on entry into the machine. Cataloguing can be done manually by a human pharmacist, but some models can identify individual boxes from a heap dropped on a conveyor belt. The interior robotic arms will then collect and store each item, and some have the capacity to hold nearly 42,000 boxes. At the touch of a button this medicine can be requested and dispensed.

Robotic pharmacies have the ability to revolutionise the way doctors and nurses deliver medicine to patients

Medicines dispensed from robotic pharmacists can be sent to different areas of the hospital through delivery tubes

Inside automation

How do robot pharmacies optimise medicine distribution?

Barcodes
Products are scanned, recorded and then loaded into the storage area.

Temperature control
Within storage areas temperatures can be set to the optimal level for medication.

Inventory
Real-time updates on stock levels and the demand of certain medicines are calculated through monitoring systems.

Medicines can be accessed and monitored through smart control panels

DID YOU KNOW? *In 2016, the global pharmaceutical industry was worth about $1,105 billion (approximately £868 billion)*

Robotic arms
Autonomous robotic arms stock and retrieve medicines, continually adjusting their location to optimise performance.

UK's first

Designed by automation experts at Swigglog, the EvoTec Pharmacy Automated Robot was introduced to Poole Hospital, Dorset, England, earlier this year. The first of its kind in the UK, it can hold up to 28,000 items organised by two robotic arms that can load and unload medicines. The arms are able to dispense around 200 items an hour and the robot monitors expiry dates from the barcodes on the packaging. Air tubes distributed throughout the hospital allow medicine to be delivered at a speedy rate, reducing patient waiting times.

Power backup
Robotic pharmacists come with an internal backup battery system to ensure these machines continually run in the event of a power cut.

Monitoring
Expiry dates and medicine preferences are continually monitored by the pharmacy robot.

The EvoTec Pharmacy Automated Robot can provide a space saving of 20–25 per cent

"Their common goal is to act as a librarian of medicine"

Autonomy in the wards

Moxi
The creation of Diligent Robotics, Moxi is the automated robot lending a hand on busy wards. Currently in trials in several Texas hospitals, Moxi uses AI mapping to carry out tasks, including collecting supplies for nurses and setting up patient rooms.

LightStrike
Protection against infection within a hospital ward is a top priority. The LightStrike can deliver high-intensity UV light bursts to surfaces in a patient's room and destroy potential antibiotic-resistant bacteria.

Pepper
With the ability to recognise faces and detect emotions, Pepper can act as an autonomous helpdesk to undertake reception duties. This robot can also act as a guide, leading patients to different departments.

THE WORLD OF WILD CATS

They may seem like furry friends, but these felines are ruthless predators

Words by **Scott Dutfield**

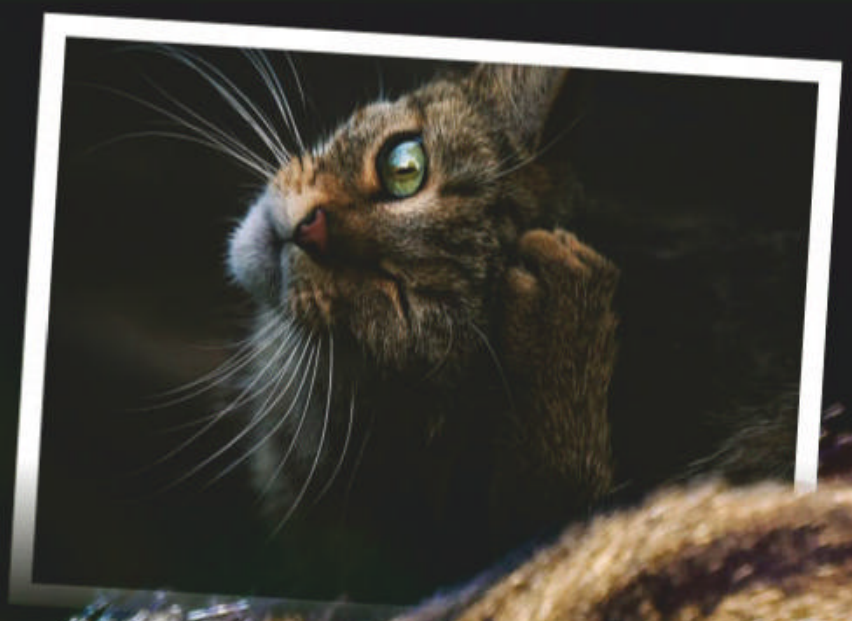
Collectively known to scientists as the Felidae family, all the world's cat species can be split into two subfamilies, the Pantherinae and the Felinae. Pantherinae are often called 'big cats' – such as lions and tigers – while the Felinae branch is comprised of the smaller examples of wild cats.

Though the Felinae are smaller, their diversity is much greater. There are over 30 species of these smaller wild cats, including the ancestor of the modern-day domestic cat: the European wildcat. Wild cats are highly adaptable and over millennia have evolved to withstand the ever-changing demands of their climate. As a fierce family of felines, the Felinae have carved out a home in almost every type of habitat, from the hostile conditions of arid deserts to the lush density of tropical rainforest.

Exclusively carnivorous, wild cats are deadly hunters equipped with retractable claws and razor-sharp teeth. They are typically solitary creatures and often nocturnal. Thanks to their patterned fur, species such as the margay and the marbled cat can stalk their prey, blending in with their surroundings. Stripes and spots allow the body of a wild cat to appear broken up against the foliage and vegetation, making it harder for prey to spot them. The same logic applies to the sand cat, which rather than having a body covered in rosettes instead has blonde fur to blend into the desert. So how did these predators go from feral to friendly and become the modern-day pets humans adore?

Humans have domesticated many different species, from cattle to wolves. Typically, the purpose of domestication is for ready access to meat and milk in cows, for example, or a form of security in dogs as guards. Cats, however, may have taken domestication into their own hands and simply merged into human society. The European wildcat likely exploited human agricultural activity and was simply tolerated or even encouraged as pest control, eventually inserting themselves as unintentional pets around 9,500 years ago.

Though domestic cats and European wildcats look alike, there are some fundamental differences between them. In a genetic sequencing study of wildcats versus domestic cats, researchers found 13 genetic differences present between the two groups. These differences relate to the cognition and behaviour of individuals, including responses to fear and learned behaviours as a result of food rewards. This biological change resulted in the transformation of the wildcat into the domestic moggy.



These agile hunters weigh around between 3.5kg and 8kg

Scratching out an existence

As one of the only remaining large mammalian predators in the UK, the Scottish wildcat has patrolled Scotland's forests for centuries. Though technically a species of European wildcat, the Scottish natives are classified as an isolated population, with some requesting they be given their own species classification. This population, however, is on the brink of extinction, with an estimated couple dozen to a couple hundred individuals left.

Several factors have played a role in the Scottish wildcat's decline, including hybridisation, deforestation, disease and human persecution. Conservation efforts have attempted to stabilise the decline through captive breeding programmes and by neutering feral cats within known wildcat territories.

With their stocky frames Scottish wildcats resemble a muscular tabby

"Wild cats are equipped with retractable claws and razor-sharp teeth"

Meet the Felinae

Discover the smaller members of the world's most diverse feline family

Chinese mountain cat
Felis bieti

Found in mountainous areas of China, these wild cats are the only cat species endemic to China. This short-legged feline has a light grey coat in the winter and brown in the summer.

Black-footed cat
Felis nigripes

One of the world's smallest wild cat species, this wild cat's body measures between 36 and 45 centimetres long. These cats inhabit desert, savannah and grassland habitats in Africa.

Pallas' cat
Otocolobus manul

Though rare in the wild, these cats are primarily distributed in the montane grassland and shrubland of central Asia. These cats are near threatened, with only 15,000 left in the wild.

Rusty-spotted cat
Prionailurus rubiginosus

About half the size of a domestic cat, the rusty-spotted cat feeds on rodents and frogs in India and Sri Lanka.

Sand cat
Felis margarita

As the name suggests, these cats are desert-dwelling felines. With the help of their large triangular ears they can detect prey both above and below the sand.

Leopard cat
Prionailurus bengalensis

Found throughout Asia, leopard cats enjoy the coverage of forest habitats from the tropical to the coniferous and successional grasslands.

Fishing cat
Prionailurus viverrinus

Unlike many domestic cats, these feline fish hunters regularly enter the water to search for prey. However, they also hunt on land for snakes, birds and frogs.

Wildcat
Felis silvestris

The mother of the modern-day cats, the wildcat is the evolutionary ancestor of our domestic pets. Wildcats can be found across Europe, Asia and Africa and have the largest range of any member of the cat family.

Jungle cat
Felis chaus

Jungle cats can be found in the wetlands across Asia and also deserts near oases in parts of Egypt. Unlike many other wild cats the jungle cat is not nocturnal.

Flat-headed cat
Prionailurus planiceps

Previously thought to be extinct, the flat-headed cat was rediscovered in Malaysia in 1995. Due to its affinity for habitats near watercourses this cat is continually threatened by water pollution and urbanisation.

Marbled cat
Pardofelis marmorata

Living high up in the tree tops, these cats blend into the forest backdrop with their mottled fur.

Wild cats like the margay often hunt their prey at night

Bay cat
Catopuma badia
Often called the Borneo Bay cat, these larger wild cats only inhabit the island of Borneo. Due to deforestation in Malaysia these cats are close to extinction, with only 2,200 individuals left.

Serval
Leptailurus serval
As one of the longer-legged wild cats, serval will jump upwards of three metres into the air, pinning their prey to the ground as they land.

African golden cat
Caracal aurata
Little is known about this elusive creature, but what we do know is that their territories are mainly in forested areas of western Africa.

Oncilla
Leopardus tigrinu/guttulus
Found across the American continent, the oncilla was split into two separate species in 2013 following genetic testing.

Guiña
Leopardus guigna
These wild cats feed on a variety of South America's bird, rodent and small lizard species.

Margay
Leopardus wiedii
Preferring to dwell among the trees, the margay has evolved to grip onto branches with its hind feet, which can rotate inwards by an incredible 180 degrees.

Pampas cat
Leopardus colocolo
The pampas cat could easily be mistaken for its domesticated cousin, however, these wild cats have distinctive striped legs.

Asiatic golden cat
Catopuma temminckii
Though typically sporting golden fur, these cats are known to sport other coats during the year, including a brown or grey version and even a spotted alternative that is similar to the ocelot's.

Caracal
Caracal caracal
As one of the largest wild cats, the caracal's body measures around 90 centimetres, with an extra 30 centimetres for its tail.

Geoffroy's cat
Leopardus geoffroyi
These spotted felines are often found in the pampas grasslands of Argentina, but they also prowl a wide variety of habitats, including temperate neotropics.

Ocelot
Leopardus pardalis
The most distinguishable feature about the ocelot is its dark, outlined stripes and rosettes. This beautiful, eccentric patterning sadly led to a boom in the international fur trade during the late 1900s.

Down the Pacific plughole

What created Thor's Well and where does all the water falling into it go?

Along a large, forested headland of Oregon, US, sits a sinkhole that appears to drain away the water of the Pacific Ocean. Named after the Norse god of thunder, Thor, the legend of the well says that in a fit of rage, Thor himself struck the Earth, creating its six-metre depth. However, the creation of this ominous formation is really thanks to the waves that fall into it.

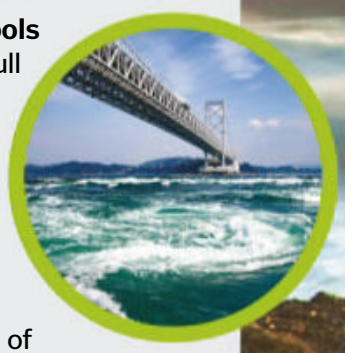
Oregon's coast, in particular the Cape Perpetua, consists of dark basalt, an oceanic igneous rock that is formed from molten magma beneath the Earth's mantle spewing into the ocean. Due to constantly flowing and colliding waters from the ocean and underground waters, subterranean caves and cavities are carved out of the basalt. It is the formation of such caves that offer the most comprehensive explanation for the ability of Thor's well to continually swallow the incoming salt water without filling up. With ocean water eroding the ceiling of the underwater cave from above it eventually collapsed, carving out the entrance of the well. This, however, doesn't explain its ability to remain empty, as a cave beneath the ground would quickly fill up.

Several theories have been suggested to explain the missing water, including a network of cavernous tunnels transporting the water elsewhere or ejecting it straight back into the ocean. One of the obvious ways the well removes infiltrating water is through fountain displays that occur as the water and air pressure builds up in the cave. When a critical pressure is reached the seawater is thrust back out of the opening in a spectacular eruption.

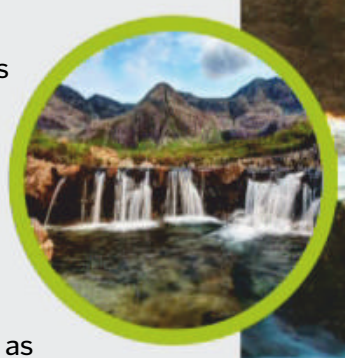
Thor's well, also known as the 'gate to hell', appears to drain away the waters of the Pacific Ocean

DID YOU KNOW? *The highest waterfall in the world is the Angel Falls in Venezuela, which measure 979 metres*

5 FACTS ABOUT WEIRD AND WONDERFUL WATER



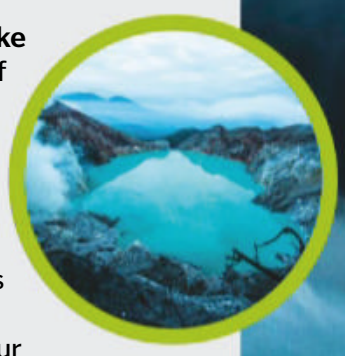
1 Naruto Whirlpools
Thanks to the pull of the Moon, whirlpools form along the Naruto Strait in Japan. During the spring and autumn seasons this water can rage at speeds of up to two kilometres per hour, creating larger whirlpools.



2 Fairy Pools
In the highlands of Scotland is a series of small waterfalls that make up the Fairy Pools. The water that fills the pools is crystal clear and is often referred to as some of the most pristine in the world.

3 Blood Falls
Bleeding through the ice in Antarctica's McMurdo Dry Valley, crimson water cascades into the sea below. Trapped beneath around 0.4 kilometres of ice, this iron-rich water travels to the glacier opening and oxidises, turning blood red.

4 Cenote Ik-Kil
The Ik-Kil In Mexico is a subterrean swimming hole formed by the collapse of its limestone ceiling. The water within this well reaches depths of over 40 metres.



5 Kawah Ijen Lake
Upon the top of the Kawah Ijen volcano in Indonesia is a kilometre-wide electric blue lake. Its vibrant colour is thanks to high quantities of sulphur and several dissolved metals within the water.

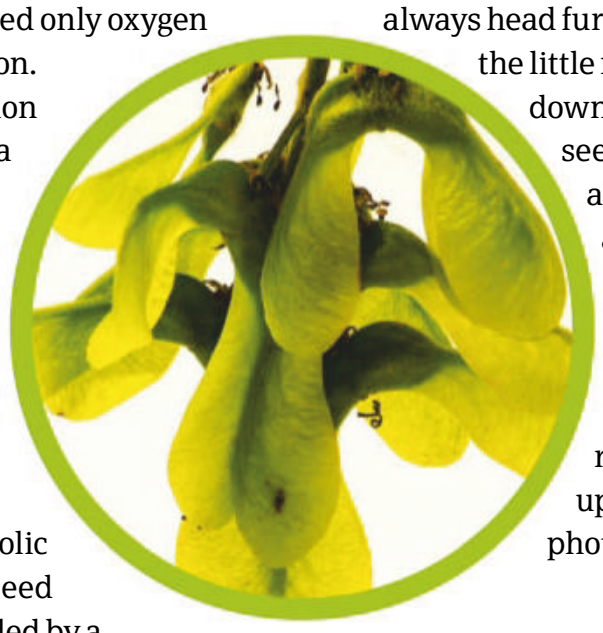
How seeds grow

A single seed is bursting with powerful natural forces that allow it to grow into the tallest tree

Every seed, no matter how tiny, is a just-add-water kit for new life. Kept safe within the seed coat is the embryo of a plant lying dormant until the moment is right to emerge and germinate. Some species require specific light or temperature conditions as well as moisture, while others need only oxygen and water to spring into action. Substances called germination inhibitors make a seed wait a year – or many years – if conditions aren't right for plant development.

When water reaches a seed, it's absorbed through a tiny opening in the coat and causes swelling as cells are rehydrated – a process known as imbibition. Metabolic processes begin within the seed and cells start to divide, fuelled by a small reserve of nutrients stored in a tissue called the endosperm or in the cotyledon, the part of the embryo that can become the first leaf. The force of the swelling causes the seed coat to burst, allowing the radicle – the embryonic first root – to emerge and anchor the seed.

Roots exhibit positive geotropism, turning in response to gravity's pull as they grow, so they always head further into the ground. Once the little root has begun its journey downwards, it can provide the seed with water and minerals absorbed from the soil around it. A shoot grows away from the root and against gravity, pushing through the soil so that the seedling's first leaves can reach the sunlight and take up the important job of photosynthesis.



Many plants have evolved dispersal mechanisms to increase the chances of their seeds landing in soil suitable for germination

Which nuts are seeds?

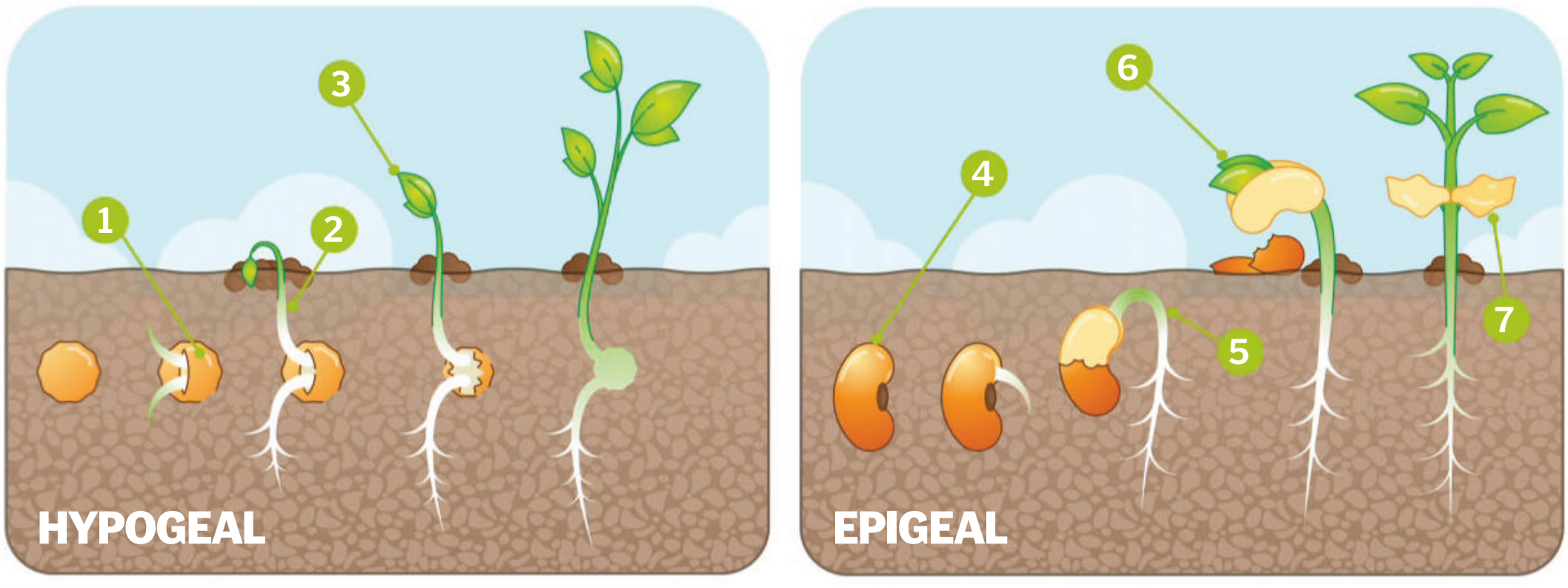
Nuts, scientifically speaking, are dry fruits that store the seed of a plant within a hard, inedible shell. True nuts include acorns, hazelnuts and chestnuts. Almonds, Brazil nuts, pine nuts, peanuts and many other 'culinary nuts' don't make the botanical cut and are actually just seeds.

Defining a bean is an easier matter. All beans are seeds – the products of the members of the Fabaceae family. These flowering plants are known as the legumes and include peas, chickpeas and runner beans. Beans are among the oldest plant crops and provide protein in the diets of many cultures. One imposter is the coffee bean; the coffee plant does not belong to the Fabaceae, making its 'bean' a simple seed.

Nuts are a surprisingly contentious topic

More than one way to grow

Developing seeds undergo either hypogeal or epigeal germination on their way to adulthood



1 Staying underground
In hypogeal (meaning 'below ground') germination, the cotyledon remains in the soil with the seed.

2 Pushing through
The epicotyl – the part of the stem above the cotyledon – grows while the hypocotyl remains the same.

3 Sprouting leaves
The first leaves of the plant develop from a growth at the end of the epicotyl that is called the plumule.

4 Breaking out
In epigeal (meaning 'above ground') germination, the cotyledon ends up above the surface.

5 Growing the hook
The hypocotyl – the part of the stem below the cotyledon – grows while the epicotyl stays the same.

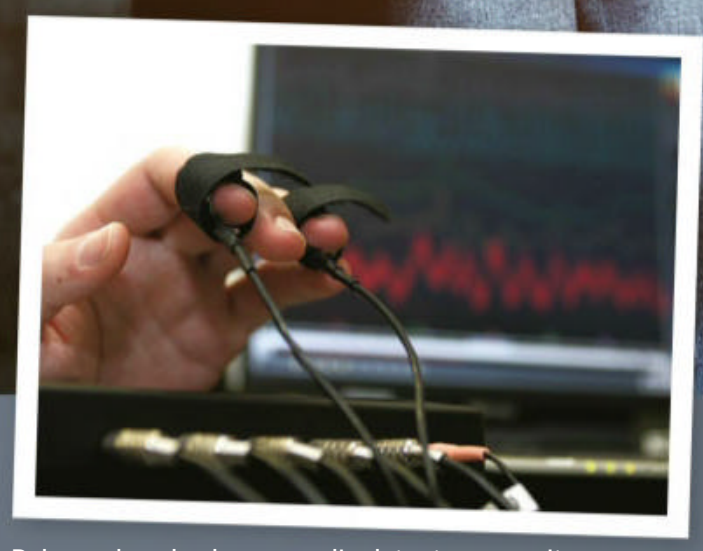
6 Revealing the leaves
Once the cotyledon has been pulled up into the open air it will quickly begin to produce the seed leaves.

7 Dropping off
Cotyledons shrivel up and fall away once the plant has grown several sets of true leaves, its crucial role fulfilled.

WHY DO WE LIE?

It's not just bad behaviour – deception is a product of evolution and it gives your brain a real workout

Words by **Charlie Evans**



Polygraphs, also known as lie detectors, monitor a person's breathing rate, pulse, blood pressure and perspiration to try to determine if someone is lying

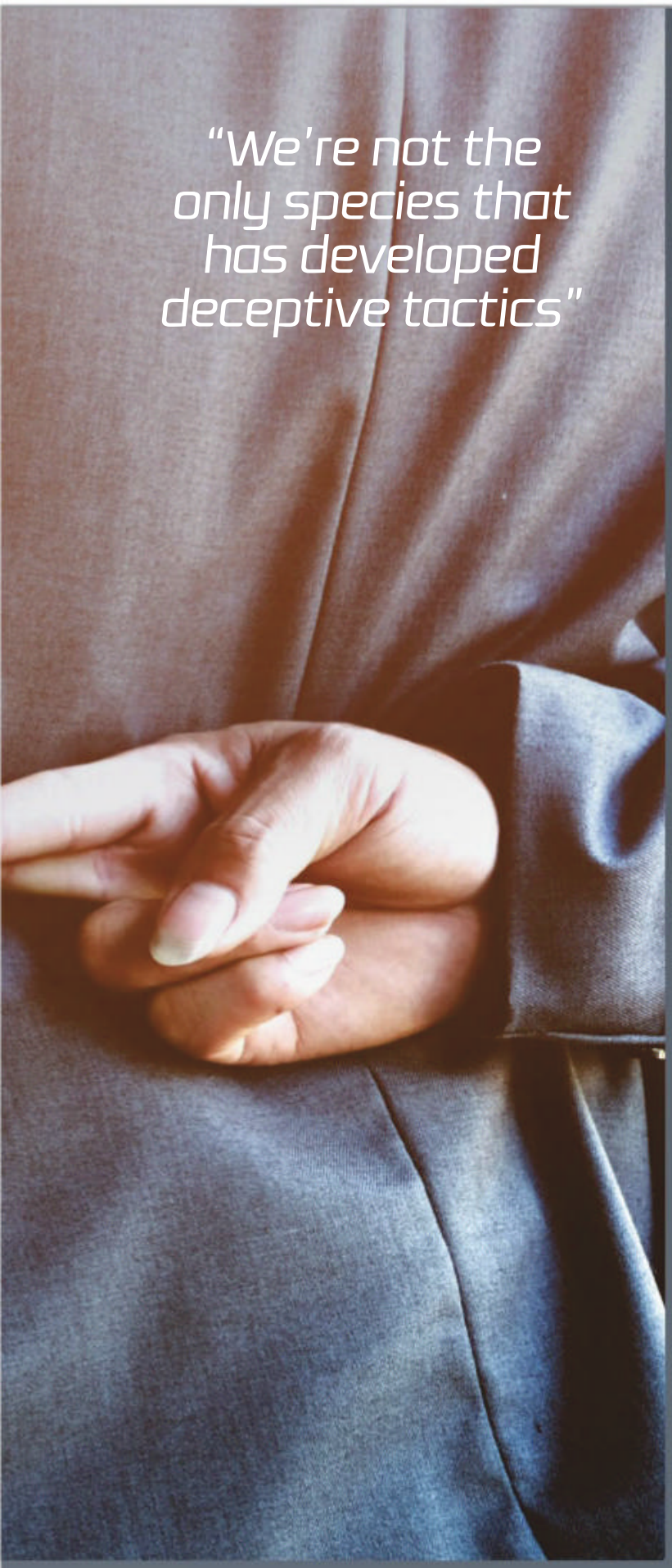
Your dog really did eat your homework, and you have no idea who took the last biscuit from the sweet jar. Lying is in your nature, but don't worry – it's in the nature of most humans. It's a technique that has evolved over billions of years, so it turns out you might not actually have that much to feel bad about.

Humans are social creatures, and we have our giant brains to thank for this. They evolved to be so large because we needed the extra space to be successful at communicating with others and keeping our social group happy. This has a lot of advantages. If you can build bonds with other humans you can access more resources because your friends and family will share food and shelter, helping you out when you need it. But to keep these close connections sometimes we need to lie. Throughout hominid history it has been a genetic advantage to be a good liar, as it supports social bonds, and therefore you are more likely to survive and pass on your genes. Bending the truth, playing fast and loose with the facts, telling a tall tale - whatever you call it, lying is something that most individuals in our species find really easy.

Although deception is frowned upon by society, it actually evolved as a way to fine-tune our social skills and strengthen our relationships. Have you ever told a friend that you really loved the dinner they had cooked for you? Or maybe you have lied to your mum about accidentally breaking something in the kitchen? That's these evolutionary mechanisms kicking in, and whether it was to protect your reputation or just avoid upsetting someone, it probably worked well to protect your relationships (if you didn't get caught that is).

YOUR BRAIN ON LIES

Lying is a creative task, and it's much harder for our brains than just telling the truth, as it requires remembering lots of different information to keep the story consistent. Even more complicated is our ability to lie to ourselves, an extreme level of deception that



"We're not the only species that has developed deceptive tactics"

When do we learn to lie?

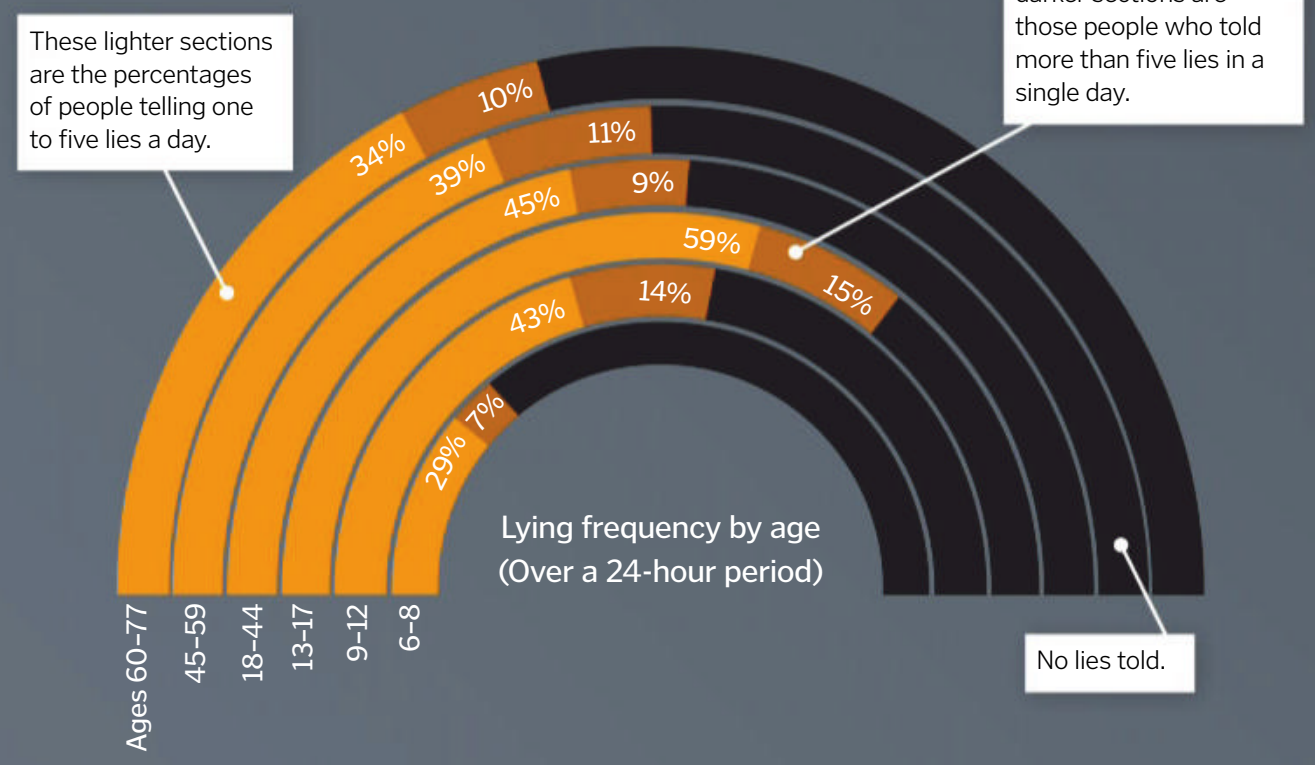
It's thought that we learn how to lie much younger than we probably think, with some research suggesting it may have begun as early as six months old. Over the years we perfect the art, and some estimates suggest by the time we are in college we may be lying to our mothers once every five interactions.

The developmental model of lying was first proposed by researchers Victoria Talwar and Kang Lee. Their work shows that children between the ages of two and three start telling primary lies – basic deceptions to cover up mistakes or bad behaviour – but without considering whether the listener will actually believe the lie. Around the age of four children start to tell secondary lies, more crafted and complex lies that are more believable. By age seven or eight children start telling tertiary lies, using consistent facts and follow-up statements. This is an ability that will stay with them for the rest of their lives.

Learning how to play games that involve a level of deception is often a vital step in learning to navigate deception as a social tool

Lying is a matter of age – honestly!

While our tendency to lie peaks in our teens, we don't all make for honest adults



© Getty

requires keeping two pieces of information in our heads and ignoring one.

Whatever reason you are lying, and however complex the lie, there are three main parts of the brain that you use when you are being deceptive: the anterior cingulate cortex, which is responsible for monitoring errors, the dorsolateral prefrontal cortex which controls behaviour, and the parietal cortex, which processes information from your senses. These parts become more active when lying, and they can be seen using functional MRI scanners – a much more advanced version of a lie detector.

However, we've not always had the technology to help us detect a liar. For most of history we have relied on our observation and social skills. We learnt how to monitor other

people's behaviours for signs they were not telling us the truth; unusual eye contact, signs they might be sweating more, elaborating on a story with details that just don't sound believable. As our ability to lie evolved, so did our ability to detect a lie. This has come in helpful because not every lie is told because we want to keep our friends. Sometimes lying is used to manipulate others for personal gains, such as scamming people out of money. Being able to detect a lie is helpful for keeping our resources safe from people who are dishonest.

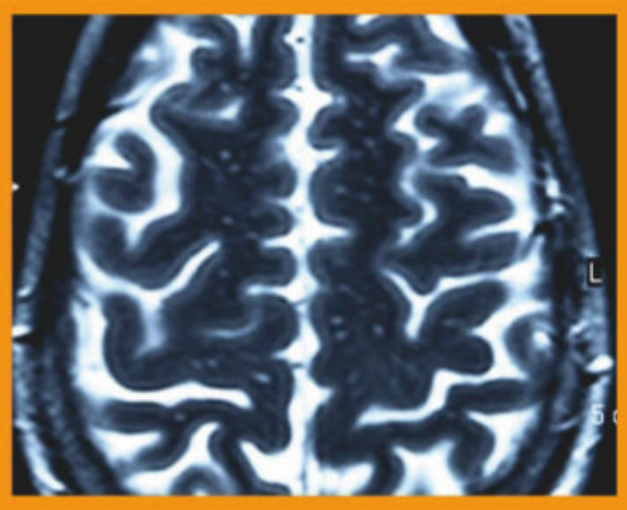
LYING IS NOT UNIQUE TO HUMANS

We're not the only species that has developed deceptive tactics. The skill has been mastered throughout the animal world, notably by tufted capuchin monkeys, which will shout out false alarms to scare away older individuals from food, and the polka-dot wasp moth, which mimics the same clicks of the bad-tasting delicate cycnia moth to ward off predators. These animals developed these tactics to protect themselves rather than strengthen social bonds.

Pathological liars

Pathological lying is a term that refers to the act of lying so naturally and instinctively that the individual finds it easier than telling the truth. Sometimes they can even believe their own lies. It is a condition that can be damaging to the lives of the sufferer as it destroys careers and relationships.

Neurologists have discovered that there are physiological differences in the brains of pathological liars, who have 22 to 26 per cent more prefrontal white matter and approximately 14 per cent less grey matter. It's thought that this difference means pathological liars are more able to make connections between different memories and ideas. However, it is unknown if the increased white matter is the cause of pathological lying or if the practice of frequently lying can cause structural changes in the brain.



It's grey matter that helps us to control our impulse to lie to others

How to catch a lie

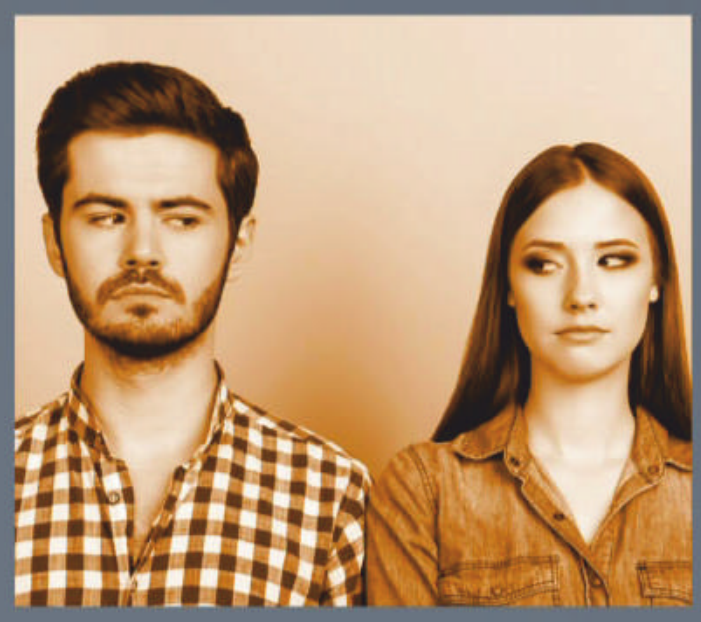
It's all in the body language

1 Intense eye contact

Eye contact usually suggests honesty, and it is tempting for someone telling a lie to break eye contact. As a result, they will start making more eye contact than usual to overcompensate.

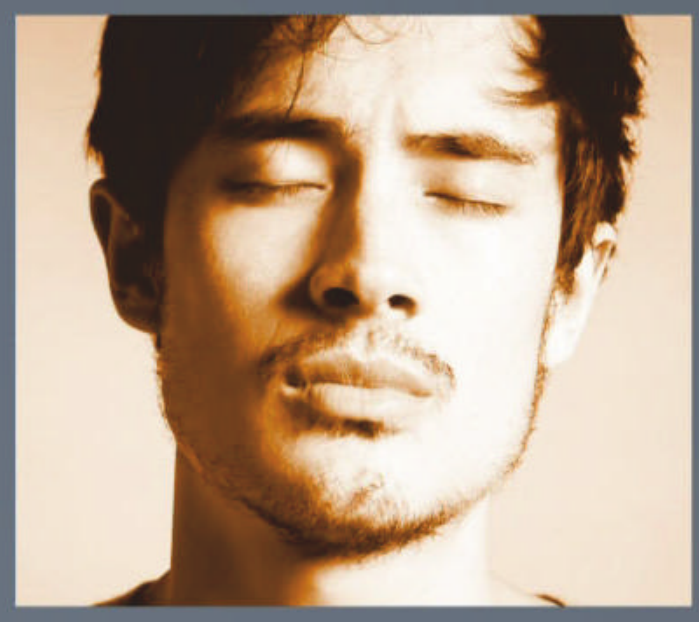
2 Contrary confirmation

Informal language and phrases that express they are being honest (such as 'believe me' or 'to be totally honest') hints that someone might not be telling the truth.



3 Frozen upper body

People tend to move less when they are being deceptive, gesturing with their hands less frequently and sometimes completely freezing their entire upper body.



4 Prolonged eye closing

Usually, people will blink for between 0.10 to 0.40 of a second, but when someone lies they often have their eyes closed for longer than a second.

5 Head shaking

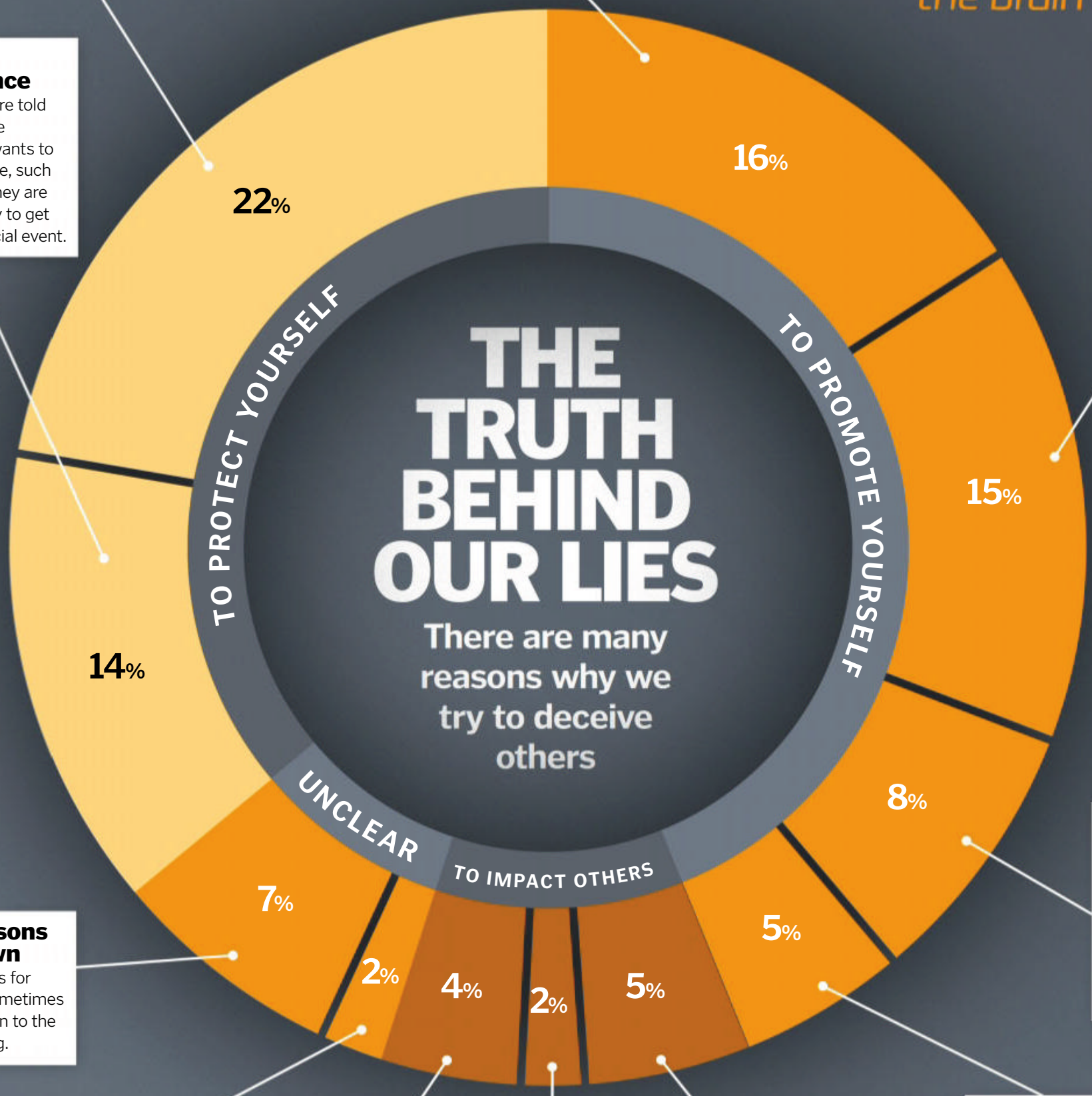
If someone says 'yes' but they shake their head 'no' at the same time, their body language might be giving away the real answer.

Cheating in a test could be an example of personal advantage or self-impression lying

THE TRUTH BEHIND OUR LIES

There are many reasons why we try to deceive others

"It is unknown if the increased white matter is the cause of pathological lying or if the practice of frequently lying can cause structural changes in the brain"



To avoid punishment
We have broken the law, made a mistake or committed a misdeed that we want to cover up.

For economic advantage
There is some financial reward, like a promotion or a pay rise that we will gain by telling this type of lie.

Social avoidance
Some lies are told because the individual wants to avoid people, such as saying they are sick or busy to get out of a social event.

For personal advantage
We are seeking a non-financial reward, such as affection, attention or higher social status.

To give a good impression
We want to shape a positive image of ourselves so lie about our character, saying we speak another language or that we're an excellent cook.

For reasons unknown
The motives for lying are sometimes unclear even to the person lying.

For humour's sake
Some lies are told for the purpose of making other people in our social group laugh, such as exaggerating a story or making up a funny anecdote that did not happen.

No real reason
Pathological lying is a condition where an individual compulsively lies to excess, often serving little or no purpose.

To fit in
Some deception comes from a desire to uphold social roles or avoid being rude in an attempt to fit in with the social group.

Malicious lying
Hurting other people by lying to them is known as malicious lying and serves to put other people down. This is sometimes done as revenge or to cover the liar's own insecurities.

Altruistic reasons
We might lie selflessly for the benefit of other people, such as offering reassurance or complimenting them to make them feel better.

2019 science events calendar

NATURAL EVENT
New Horizons flies by Ultima Thule.

LAUNCH
Chandrayaan-2 – Launch of the lunar orbiter, lander and rover from the Satish Dhawan Space Centre in Sriharikota, India.

TALK – 7 FEB–21 SEPT
Professor Brian Cox's 'Universal' World Tour begins (starts in the UK).

FESTIVAL
13–16 MAR
The Big Bang Science Fair at the NEC Birmingham.

TALK
Jim Al-Khalili: 'A Brief History of Gravity', George Abbot School, Surrey.

JANUARY

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TALK
'Liquid: Delightful and dangerous substances', with Mark Miodownik at the Royal Institution, London.

TALK
The life of Lise Meitner

In honour of physicist Lise Meitner (1878–1968), the Churchill Archives Centre is holding a one-day symposium featuring three panels exploring her life and work.

FEBRUARY

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LAUNCH
Launch of SpaceX Falcon 9 – CRS 17 – at Cape Canaveral, Florida.

EXHIBITION
Imperial Lates: Smart Fashion at Imperial College London.

EXPERIMENT – 15–18 FEB
Great Backyard Bird Count

The Cornell Lab of Ornithology and National Audubon Society encourage the British public to count the birds in their back garden as part of an online citizen-science project to collect data on wild birds.

CONCERT
13–28 MAR
Blue Planet II in Concert (various locations in the UK).

MARCH

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TALK
'The Human Martian', at The Royal Institution of Great Britain, London.

COMEDY / TALK
BAHfest and Ig Nobel Prize EuroTour inside the Great Hall at Imperial College London.

The Festival of Bad Ad Hoc Hypotheses, a celebration of well-argued and researched but incorrect scientific theory, and the Ig Nobel Prize, awarded to unusual achievements in science, combine forces for one evening in London.

EXHIBITION – 1–7 JUL
Royal Society Summer Science Exhibition 2019 in London.

WORKSHOP ENDS
26 JUL–2 AUG
The Cambridge Coding Summer School.

SCIENCE FESTIVAL – 10–13 SEP
British Science Festival hosted by the University of Warwick, Coventry.

JULY

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AUGUST

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NATURAL EVENT
- 12-13 AUG
Perseid meteor shower.

SEPTEMBER

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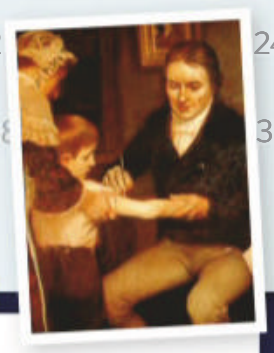
CONFERENCE – 9–11 JUL
UK Space Conference at International Convention Centre, Wales.

SCIENCE MUSIC FESTIVAL – 18–21 JUL
Bluedot Festival, Jodrell Bank Observatory in Macclesfield, Manchester.

ANNIVERSARY
50th anniversary of Apollo 11 Moon Landing

This month we're celebrating the anniversary of the first landing on the Moon in 1969. On this day 50 years ago Neil Armstrong and Buzz Aldrin's lunar module had been on the lunar surface for 21 hours and 36 minutes.



MINI-FESTIVAL
Dr Jenner's House Discovery Day

A day looking at the kind of work Edward Jenner would be carrying out if he were alive today, in the place where he pioneered the invention and development of the vaccination.

FESTIVAL - 13–15 SEP
Yorkshire Fossil Festival at the Rotunda Museum, Scarborough.

FESTIVAL – SEP DATE TBC
Gravity Fields Festival

This festival in and around Grantham, Lincolnshire, celebrates Sir Isaac Newton's legacy with five days of talks, workshops and exhibitions with world-leading scientists and specialists.

Comedy to concerts, exhibitions to space launches, we've selected an unmissable line-up of things to see and do in the new year

TALK – 5–6 APR
Russian Air Force officer and cosmonaut Gennady Padalka at Carleton Community High School 'The Infinity Theatre'.

SCIENCE FESTIVAL – 6–21 APR
Edinburgh International Science Festival.

CONFERENCE – 8–10 MAY
Devoxx conference for software developers, Business Design Centre, London.

FESTIVAL – 4–9 JUN
Cheltenham Science Festival.

TALK
The Stamford Raffles Lecture, ZSL London Zoo, to be given by Professor Carl Jones.

APRIL

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COMEDY
An evening of unnecessary detail at the Backyard Comedy Club, Bethnal Green, London.

TALK / SCREENING
'Let there be Light' trailer and panel at the Science Museum London.

SCIENCE SHOW (ENDS)
Anatomy Lab LIVE

A surgical spin on dinner, this nationally acclaimed dinner and dissection experience is back and bigger than ever, with trained physicians taking you through a trip of the human body.

MAY

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TALK – 20–22 MAY
Pint of Science (various)

Pint of Science is a casual event hosted around the UK that brings scientists to your local pub for presentations on their latest discoveries.

FESTIVAL
30 MAY–4 JUN
The 10th Annual World Science Festival in New York.

JUNE

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SCIENCE MUSIC FESTIVAL – 24–29 JUN
Starmus V in Bern, Switzerland.

WORKSHOP
Robotics & Coding Day Camp: Mission to Mars at College Park School, London.

Tackled robot repair and coding challenges at day camps for seven- to 12-year-old children interested in coding, robotics and technology.

OCTOBER

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NATURAL EVENT
Meteor showers

The Draconids, Orionid and Taurids meteor showers will be visible throughout October. The Orionid shower is one of the best known in the annual calendar, and is associated with Halley's Comet.

COURSE
Wildlife Crime and the Law, The Holly Lodge Centre, Richmond Park.

FAIR
The ultimate STEM graduate recruitment fair at the Barbican Exhibition Centre.

NOVEMBER

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EXHIBITION - FROM 24 NOV
'Eco-visionaries' at Royal Academy of Arts in London.

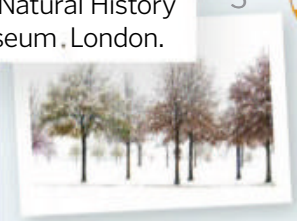
SHOW
Robot Wars: Extreme

The robots of *Robot Wars* have left the studio and are entering the Extreme Arena. This is your chance to watch the robots battle it out live in Cheltenham.

DECEMBER

SUN	MON	TUE	WED	THU	FRI	SAT

ACTIVITY
Winter Tree Identification by The Species Recovery Trust at the Natural History Museum, London.



CONCERT / TALK - DATE TBC
'Nine Lessons and Carols for Curious People', London

The Cosmic Shambles Network hosts this annual festive variety night with Robin Ince and a panel of scientists for an evening of comedy, music, poetry and science.

TALK - TBC
Christmas Lectures in London.

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How air fresheners work

These scented products are able to neutralise, mask or absorb bad odours

Whether it is emitting from the back of the fridge, the dog's bed or the bathroom, we're all familiar with bad smells. These odours are caused by chemicals that vaporise at low temperatures then travel through the air to reach our noses. Such smells are grouped into five categories: lavatory odours, tobacco smoke, stale cooking smells, pet odours and mouldy odours, and we really hate them – the UK spends £1 million a day on air fresheners.

Air fresheners are one of the ways we can get rid of offensive odours. Once limited to just sprays, the market today is filled with scented gels, potpourri, plug-ins, incense burners, beads, oils and waxes. Whether you're spraying air freshener, using a scent plug-in or burning a scented candle, the active ingredients are all made of volatile chemicals that easily turn from a liquid into a gas at room temperature. These ingredients range from materials like activated charcoal and silica gel, which absorb smells, to chlorine and hydrogen peroxide that act as oxidising agents to break down organic scent molecules. Other products aim to overwhelm the source of the bad smell by filling the air with the molecules of scents that are more pleasing to the nose.

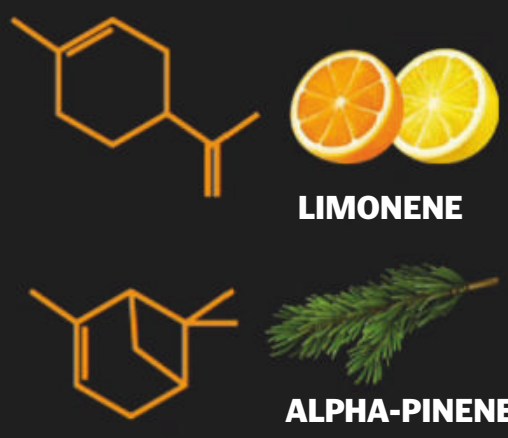
There are alternatives to tackling smells; you could open a window, or track down the source of the smell, but air fresheners often provide quicker and more pleasant results.

The chemistry behind air fresheners

There are several types of compounds in air fresheners that combat bad smells

Fragrances

Terpenes, such as limonene and alpha-pinene, can be used to mask bad odours by overpowering them.

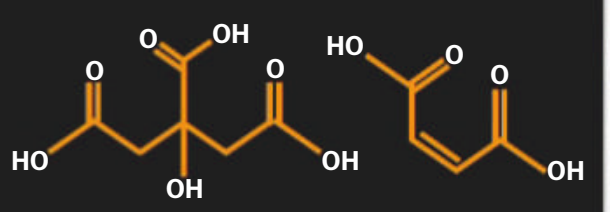


LIMONENE

ALPHA-PINENE

Odour neutralising

Organic acids can be used in air fresheners to break down bad-smelling compounds into more neutral molecules.



CITRIC ACID

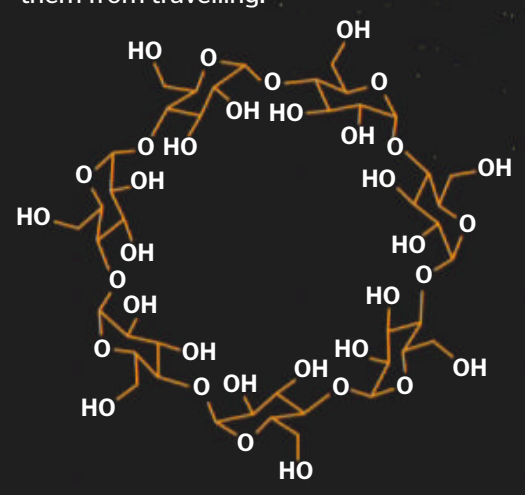
MALEIC ACID

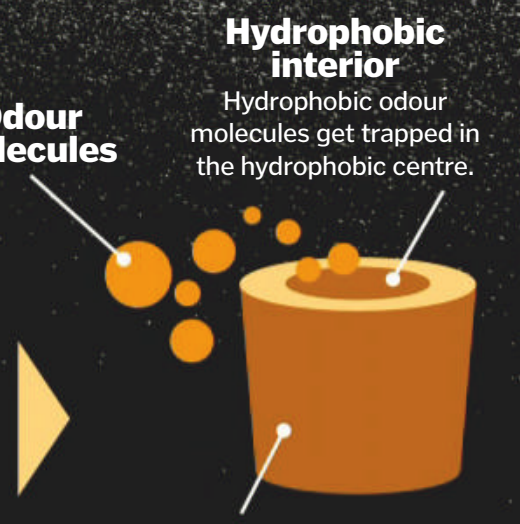
A diffuser works by drawing up the liquid through a reed, which then disperses the scent through the air

The mist created by aerosol air fresheners contains droplets 50 to 150 micrometres in diameter

Odour trapping

Cyclodextrins are ring-shaped molecules made from cornstarch that can trap odour molecules and prevent them from travelling.





Safety concerns over air fresheners

A report from the Bureau Européen des Unions de Consommateurs (BEUC) in 2005 found that many air freshener products contain dangerous pollutants, including allergens and toxins such as toluene, formaldehyde and terpenes.

Limonene is a terpene responsible for creating citrusy scents. While limonene isn't dangerous itself, studies have revealed on exposure to ozone (a gas that is found in the air around us) it transforms into something more dangerous. Every two molecules of limonene in the presence of ozone produces one molecule of formaldehyde, a known cancer-causing chemical. However, they're usually used in such small amounts that air fresheners are not considered to be dangerous.

If you're concerned about the molecules in air fresheners, you could consider including more houseplants around your home that have been shown to absorb such chemicals, like English ivy (*Hedera helix*).

REMOTE-CONTROLLED EXPLORERS

How robot avatars could take us to exciting new worlds without us having to leave Earth

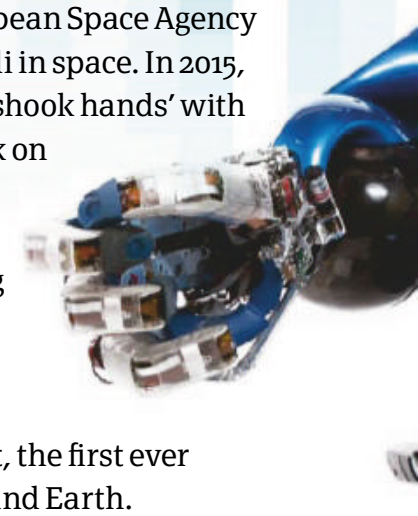
Words by **Jonathan O'Callaghan**

Telerobotics might sound like something out of science fiction, but chances are you have had quite a lot of interactions with it. Have you ever driven a remote-controlled car, used virtual reality, or heard about a spacecraft docking with the International Space Station (ISS)? Then you've probably got a good idea of what telerobotics is.

This is the idea that robots can be operated remotely by humans in another location, and on Earth there are many uses for telerobotics. We send submersibles into our oceans (that are controlled by humans on land) to explore parts of the ocean that are difficult for humans to reach. We also use them to explore areas high in radiation, such as Japan's Fukushima reactor, which would be deadly for humans to explore. We're even starting to use remote surgery, known as telesurgery, to allow doctors to operate on patients they can't reach.

When it comes to space travel, there are a range of interesting ways that telerobotics could be used in the future and many that are being used already. This includes enabling astronauts to operate machinery on Earth, perform activities in space without venturing outside or even exploring strange new worlds. Astronauts have been busy practising how to control rovers on Earth from the ISS, using controls on the station to move and operate robotic arms and other instruments.

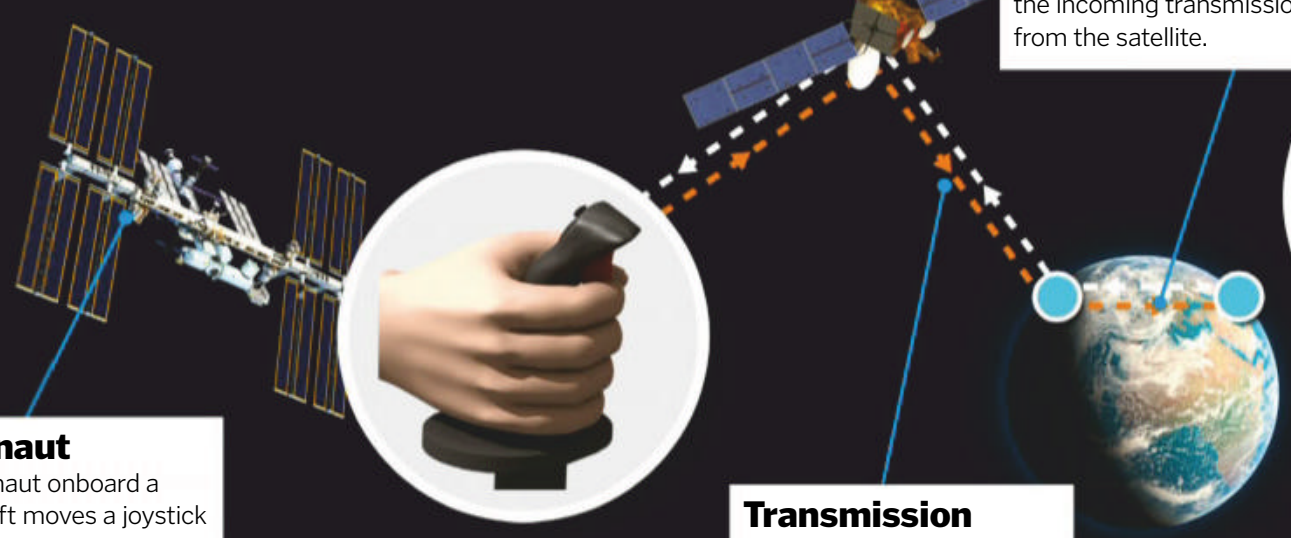
This includes the German Aerospace Center's (DLR) Rollin' Justin humanoid robot, which has movable limbs and hands that astronauts can control from orbit, and cameras so the astronauts can see what the robot is doing. In 2017, it was controlled on Earth by European Space Agency (ESA) astronaut Paolo Nespoli in space. In 2015, NASA astronaut Terry Virts 'shook hands' with a telerobotics specialist back on Earth. Virts was using a joystick on the ISS, with another on Earth mimicking his actions. Using haptic feedback, Virts was able to 'feel' a handshake from the operator on our home planet, the first ever handshake between space and Earth.



The idea is that in future these techniques could enable more rapid and easier exploration of other worlds like Mars. We have sent several rovers to Mars, all of which are controlled from Earth. Engineers input commands for the rover to carry out, and the rover then acts out those

Telerobotics in action

How astronauts use telerobotics to drive robots on Earth



Astronaut
An astronaut onboard a spacecraft moves a joystick or lever to initiate an action.

Transmission
Each movement is transmitted via satellite back to the surface of Earth.

Instruction received
The robot on Earth receives the incoming transmission from the satellite.

Action
The robot performs a corresponding action to the astronaut, such as moving an arm.

DID YOU KNOW? *NASA is considering sending a radio telescope to the lunar surface that could be teleoperated by astronauts*

The Rollin' Justin robot's wacky limbs make it easier to control

The Avatar X Lab in Kyushu, Japan, will be used for lunar experiments, with the location chosen for its resemblance to the Moon's surface

"There are a range of ways telerobotics could be used in future"

commands. But it takes an average of 14 minutes for a command to reach the Red Planet, making progress slow.

Rovers have typically only been able to travel up to tens of metres per day or perform simple tasks like scooping up material from the surface. In the future, however, we may well have astronauts in orbit around Mars. While we might one day also set foot on the Red Planet, there are many unknowns before that can happen. But astronauts orbiting Mars could operate robots on the surface almost in real time, enabling much more complex missions that can accomplish a lot more than those that are controlled from Earth. This form of telerobotics also eliminates the human risk factor. Mars is a dangerous place, but if the astronauts can remain safely in orbit then we may be able to study Mars in detail much sooner than if we had to wait until we could send humans to the surface.

Before Mars, it is likely these techniques will also be used to explore the Moon. NASA and its international partners are currently developing a space station that could orbit near the Moon in the coming decade called the Deep Space Gateway (DSG), in which astronauts could live

5 FACTS ABOUT TELEROBOTICS PROS AND CONS

1 Remote operations
Telerobotics enables astronauts to operate a machine from afar without travelling there themselves, which could be very useful on places like Mars.

2 Lower risk
Without the need to travel to potentially dangerous environments, remaining in the safety of a spacecraft can reduce the risk to human life.

3 Quicker missions
Telerobotics could make missions to other worlds more feasible in a shorter timeframe, as we won't need to develop the technology to land humans.

4 Time delay
It does still take some time for the signal to travel to the robot, which means that actions are not performed in completely real time.

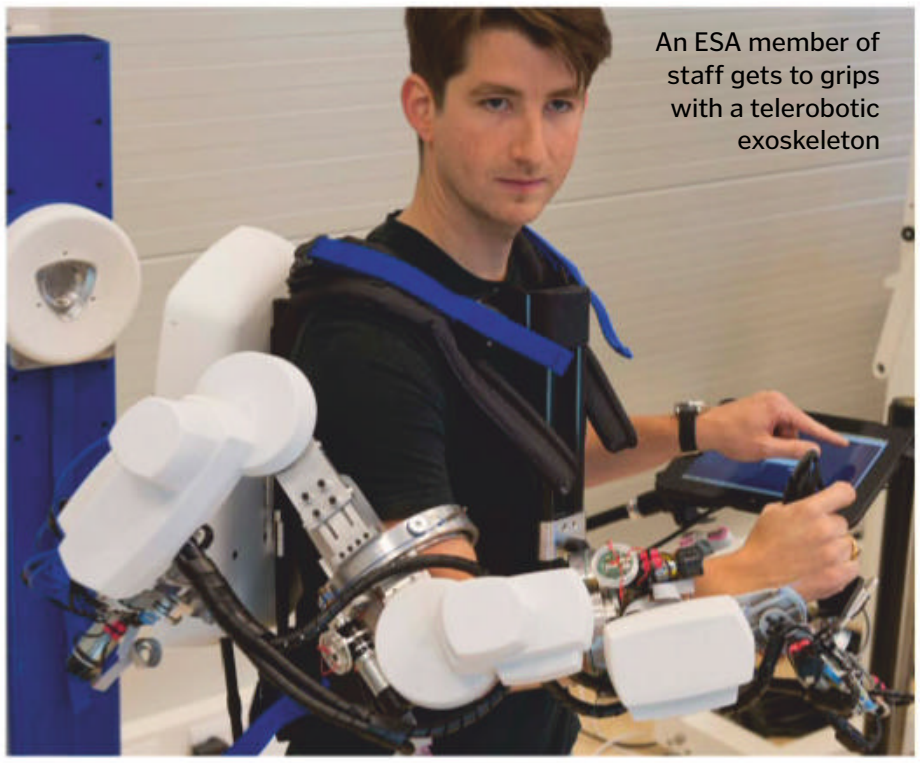
5 Line of sight
When an astronaut loses sight of a robot, such as when they orbit to the other side of a planet, they will lose control of it.

and work just like on the ISS. These astronauts could control a number of robots on the Moon, such as rovers to build habitats that they can live in for long periods of time or machines that can explore the dark but fascinating craters of the Moon that would be dangerous for humans to venture into.

Looking far into the future, some even more exciting possibilities start to spring up. Worlds like Jupiter's icy moon Europa and Saturn's equally frosty moon Enceladus may have life-harbouring oceans hiding beneath their surface. But being locked beneath tens of kilometres of ice, the chances of humans exploring these places seem slim at best. What if instead, a robotic submarine (one controlled by humans on Earth or perhaps even orbiting nearby in space) could melt its way through the surface of one of these moons before swimming through the watery depths below?

There are still issues to iron out with telerobotics. One is that astronauts need to be in sight of any robot they are operating. If they are not, such as when they are orbiting on the other side of the Moon to a robot on the surface, they will not be able to communicate unless a relay satellite is used to bounce their signal off. Another is the amount of bandwidth available, and therefore the amount of data that can be sent to the rover, which could limit activities. Further still, while the time delay is reduced by having astronauts nearby, it is not eliminated, and even a slight lag of a few seconds can cause problems if a robot gets into a sticky situation.

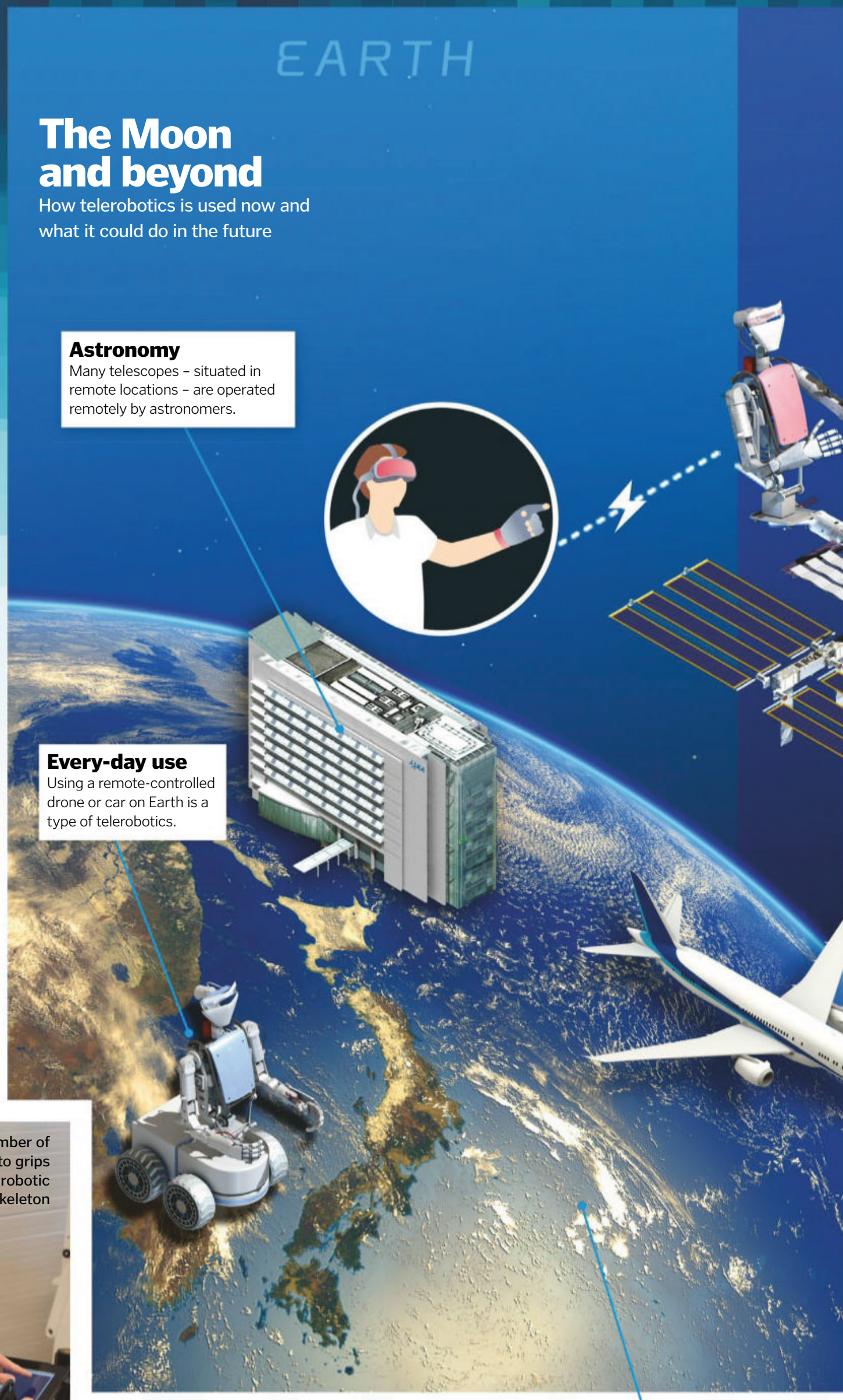
Even so, there's little doubt that the future of telerobotics could be thrilling. By enabling more rapid exploration of other worlds, it could give us a way to explore interesting locales without having to risk the lives of humans. Who knows, maybe one day an astronaut will get to drive a remote-controlled car on Mars, just like they once did on Earth.



An ESA member of staff gets to grips with a telerobotic exoskeleton

The Moon and beyond

How telerobotics is used now and what it could do in the future



"The future of telerobotics could be thrilling"

LOW EARTH ORBIT

MOON, MARS & BEYOND

International Space Station
A robotic arm called the Canadarm2 is used by astronauts on the exterior of the ISS.

Lunar construction
Future telerobotics missions could involve using robots from afar to build on the Moon.

Beyond Mars
Other worlds like Jupiter's moon Europa could also be explored using telerobotics from far away in the future.

Mars
Before humans set foot on Mars, they may control robots on its surface from Martian orbit.

Moon exploration
Using telerobotics it's possible to explore the Moon with a rover with just a few seconds delay.

The K10 rover was controlled on Earth by astronauts on the ISS

Space rover

In 2013, NASA astronaut Chris Cassidy and ESA astronaut Luca Parmitano both successfully operated a rover at NASA's Ames Research Center in California from the ISS. This was the first time a robot on Earth had been completely controlled by astronauts in space. The four-wheeled robot, called K10, was equipped with a scanning laser system and multiple cameras so that the astronauts could see what they were doing, letting them drive across the ground and complete tasks. Cassidy successfully used the rover to navigate rocky Moon-like terrain, while Parmitano used the rover to deploy an antenna, something that might need to be done on a real lunar mission one day in the future. The project was seen as being a key test in proving that astronauts could operate rovers on the surface of another world.

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Redshift and blueshift

How this weird phenomenon can help us study the distant universe

If you've ever heard a police car drive by with its sirens blaring, you'll be able to understand redshift and blueshift. As the car went past you probably noticed that it sounded higher pitched as it approached you and lower pitched as it drove away. This is known as the Doppler effect, and it's caused by sound waves being pushed closer or further away from each other.

The same thing happens with light. It turns out that as a light source moves towards or away from us on a large scale, the light also gets shifted – but in this case its wavelength on the electromagnetic spectrum gets shorter or longer. Wavelength is basically an energy pattern in light that determines what colour it is. Longer wavelengths correspond to red, while shorter wavelengths correspond to blue or violet.

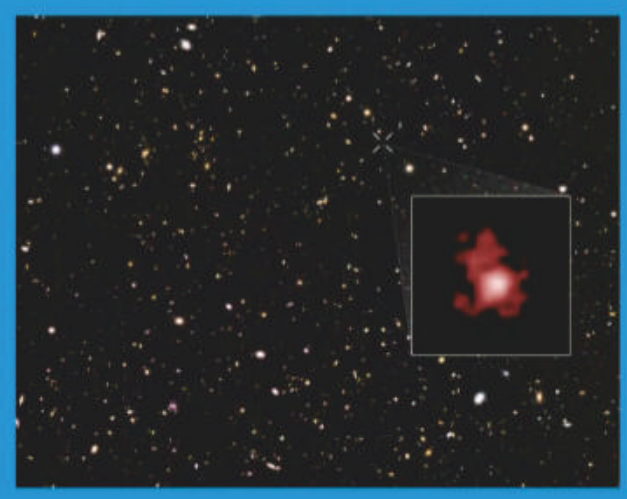
When we observe a galaxy in the universe, we find that its light is generally either redshifted or blueshifted. The former is more common, as the universe is expanding and everything is moving away from everything else. The more distant a galaxy is – and thus the faster it is moving away from us – the higher its redshift is.

A few galaxies, like the Andromeda Galaxy, are moving towards us however and are on a collision course with our Milky Way. Andromeda's light is blueshifted. Galaxies that are spinning can also exhibit a slight blue or redshift, as one side of the galaxy moves towards us while the other moves away from us.

The Andromeda Galaxy is moving towards us, so its light is blueshifted

The most distant galaxy

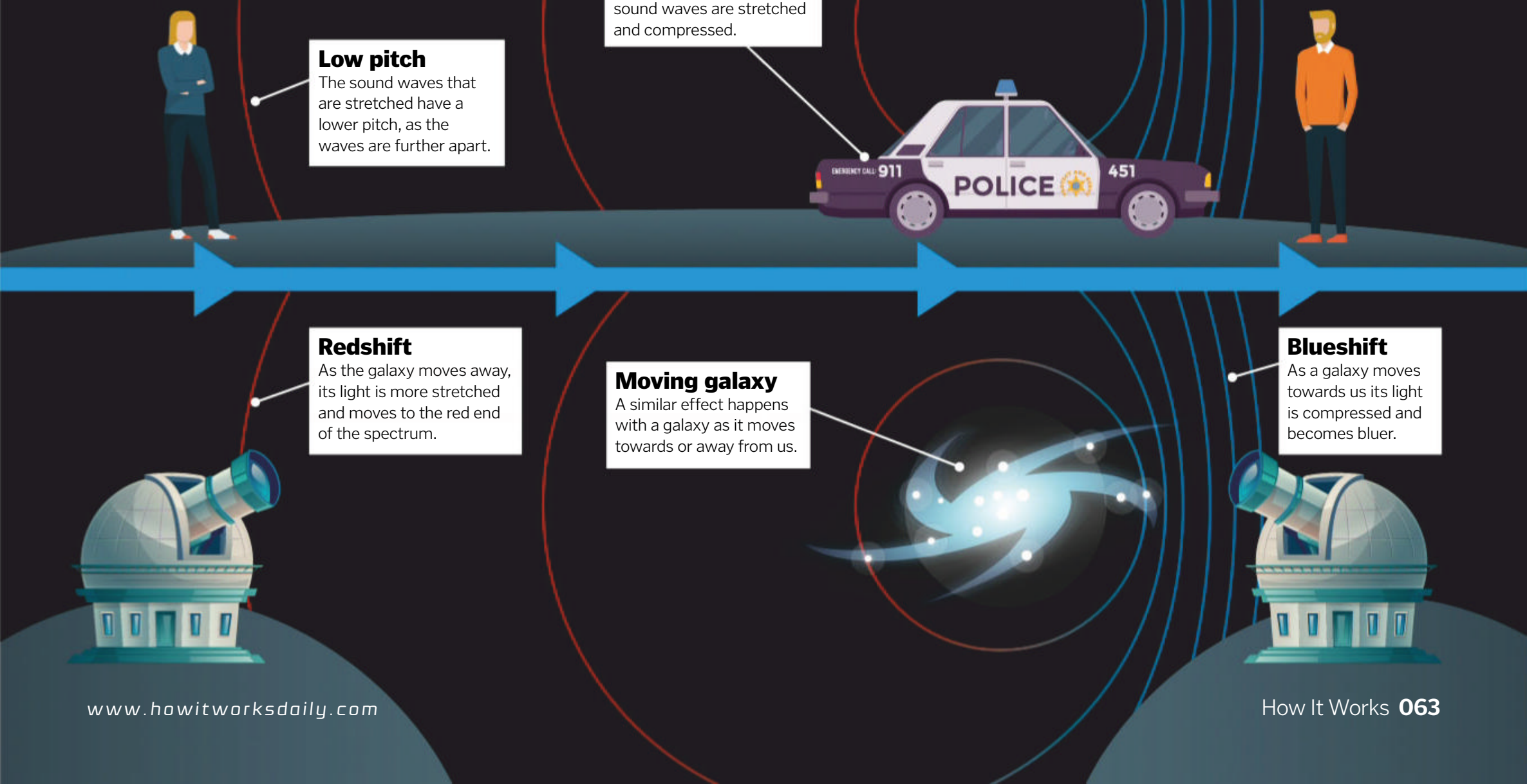
We can use redshift to measure how far away the most distant galaxies we can see are. As a galaxy increases in speed and thus gets further away, its redshift increases. Currently, the most distant galaxy we've seen in the universe is GN-z11, which has a redshift value of 11.09. This corresponds to a distance of 13.4 billion lightyears in terms of how far the light has travelled to reach us across the universe. This also means we are looking far back in time, to just 400 million years after the Big Bang. Astronomers are now hoping to look even further back towards the Big Bang itself to find some of the first galaxies that formed in the universe.



The bright infant galaxy GN-z11 is located in the direction of the Ursa Major constellation

Pushed and pulled

How a moving object can change both its sound and light



CIRCUMNAVIGATING THE GLOBE

The intrepid explorers whose expeditions led them around the world

Words by **Charlie Evans**

On 6 September 1522 the tattered ship Victoria sailed into the port of Sanlúcar de Barrameda. Her sails were badly torn, and she was only being kept afloat by the continuous pumping out of the water that was filling up her hull. The crew had been months without food. As they sailed back home to Spain they had been forced to resort to killing and eating rats that were infesting the ship and drinking putrid water that had been stored for months. Over the previous three years they had survived mutiny, execution, disease, starvation and dehydration. Victoria was one of five ships that had set out to find a new route to the Spice Islands, but she was the only ship to return, carrying her starving crew of just 18 men. These men were the first to navigate around the entire world – a feat that would not be accomplished for another 58 years.

The earliest circumnavigations were driven by curiosity, fame and wealth. These sailors would discover new lands and trade routes and would return home as heroes. But humans were not content with just mastering circumnavigation on water. Instead, our expeditions and our ambitions were to become even bigger. First we conquered circumnavigation by sea, and then we took to the skies, before Soviet cosmonaut Yuri Gagarin faced the final frontier and completed the first orbit of the Earth in space.

A global circumnavigation is generally recognised as a great circular route that passes through at least one pair of points on the opposite sides of the Earth to each other. The rules for a round-the-world sailing record dictate

that the length of the voyage must be at least 21,600 nautical miles and that the equator must be crossed at some point along the journey.

Today we have more technology to keep circumnavigators safe, their supplies stocked up and their journey more comfortable. This includes accurate GPS systems and extensive maps to guide them, advanced weather warnings, knowledge about political situations, extensive maps and robust ships.

The first ships built for circumnavigation were carracks: three or four-masted ocean-going sailing ships that were large enough to stay stable in rough seas and carry enough cargo and provisions for long voyages. Sailors would rely on equipment and (inaccurate) maps to navigate their route. In addition to their basic magnetic compass they used a backstaff to measure the angle of the shadow of the Moon or Sun to determine latitude measurements and assist them with navigating the oceans. They also relied on a lead line that was dropped into the water to touch the ocean floor, which was marked and pulled back up to measure how deep the ocean was at that point.

Modern circumnavigators have replaced most of this kit with high-tech versions that calculate the same information, such as a gyro compass, which is more accurate and is not affected by an external magnetic field. Modern ships are also fitted with Automatic Radar Plotting Aids that display the position of a ship and any vessels nearby to prevent collisions. Echo sounders are also used instead of lead line. They work by bouncing sound waves off the ocean floor to measure the depth of the water below the ship.

If you're feeling inspired, you don't actually need to learn how to sail a boat or start building up your leg muscles to hit the road with a bike. Instead, you could circumnavigate the world using only commercial flights. It just takes quite a bit of money and some careful planning, particularly to limit the amount of time you're hanging around in airports, but you could even attempt to set a new record.

The record for doing this is held by David Springbett, who completed a 37,124-kilometre circumnavigation (under FAI regulations) in just 44 hours and 6 minutes back in 1980. Unfortunately, you're probably not going to be able to beat his record today because he had a massive advantage; some of his journey was made in one of the fastest passenger planes in history - Concorde, which could reach speeds of 2,160 kilometres per hour. The fastest routes using modern aircraft would take over 50 hours.

However you choose to circumnavigate the world, you probably won't have the same fate as Magellan and his crew thanks to the new technology we have at our fingertips.

Historic firsts in circumnavigation

Whether on land, over sea or in space, these pioneering journeys were driven by curiosity, determination and a hunger for adventure

1,083 days

Ship 1519–1522 Magellan's crew

21 days, 5 hours and 31 minutes

Zeppelin 1929 Dr Hugo Eckener

19 days, 21 hours and 55 minutes

Hot air balloon 1999 Bertrand Piccard and Brian Jones

175 days

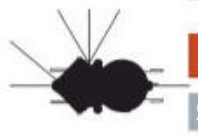
Plane (with stops) 1924 Lts. Lowell Smith, Leslie Arnold, Lts. Erik Nelson and John Harding Jr.

94 hours and 1 minute

Plane (non-stop) 1949 Captain James Gallagher

9 days, 3 minutes and 44 seconds

Plane (non-stop, no refuelling) 1986 Dick Rutan and Jeana Yeager



108 minutes

Spacecraft 1961 Yuri Gagarin

In 1987, the Indian Army Corps of Engineers completed the first circumnavigation by an Indian crew on a yacht called Trishna

"They had learnt that the world was a globe, not flat as was believed at the time, and they discovered new islands that had never been mapped"

Magellan's circumnavigation of the world

Ferdinand Magellan had one goal when he sailed from Seville on 10 August 1519: he wanted to find a western trade route for Spain to the Spice (Maluku) Islands.

This small cluster of islands to the northeast of Indonesia had become an important location to source nutmeg and cloves – spices that were worth 1,000 per cent more than their cost in the Spice Islands. 270 men joined Magellan's voyage in five ships: Trinidad, San Antonio, Conception, Santiago and Victoria. Trinidad was the flagship and commanded by Magellan himself. They sailed from Spain to South America, across the South Pacific Ocean to Oceania, before reaching Southeast Asia, crossing the Indian Ocean to Africa, eventually sailing along Africa's west coast back up to Spain.

They had lost most of their crew, but they had made great discoveries. They had learnt that the world was a globe, not flat as was believed at the time, and they discovered new islands that had never been mapped. Most importantly, they had established a new trade route for the Spanish to reach the Spice Islands and had returned with one ship filled with a king's ransom in cinnamon and cloves.

This illustration of the Trinidad was drawn by Abraham Ortelius

© Getty; Wiki; Pixabay

The challenges of circumnavigation

Storms, pirates, and rough seas – travelling the globe is no easy feat

Margarita Island
The largest island in the Venezuelan state of Nueva Esparta in the Caribbean Sea has recently seen a spate of pirate boardings in the area, and most ships avoid the route.

Cape Horn
The storms off Cape Horn make the area difficult (often) impossible to navigate. Sailors who do attempt to use the route risk having their ship grounded on the rocks off the coast.

The intertropical convergence zone
This area is where winds from the Northern and Southern hemispheres meet, which can cause violent and unpredictable thunderstorms that could pose a threat to aircraft.

Drake Passage
Drake Passage at the southern tip of South America is one of the roughest seas in the world and has been responsible for many shipwrecks.

Hurricanes

Hurricanes

Suez Canal

The Suez Canal is used by pirates to target larger vessels, particularly for food. Cruise ships that pass through switch off their lights at night to pass by less conspicuously, while solo travellers usually avoid the canal.

Tibetan Mountains

The Tibetan Mountains are so high that most aircraft will not attempt flying over them, instead taking the longer route around but without the risk of their plane being destroyed on the mountain face.

Gulf of Aden

This dangerous shortcut is nicknamed 'Pirate Alley' and is historically associated with kidnappings and the boardings of ships.

Cyclones

These rapidly rotating storm systems can be dangerous to any vessel attempting a circumnavigation and must be avoided.

The Indian Ocean

The Indian Ocean has a warm temperature and an ever-changing climate, making it prone to erratic weather conditions that can make navigation difficult or dangerous.

5 FACTS ABOUT AMAZING CIRCUMNAVIGATIONS AROUND THE WORLD

1 Fastest aerial circumnavigation
In 2005, Steve Fossett set the record for the fastest non-stop aerial circumnavigation in 67 hours and 1 minute, and covered 37,000 kilometres flying a Virgin Atlantic GlobalFlyer.

2 First underwater circumnavigation
The submarine USS Triton completed the first underwater circumnavigation in 1960 in just 60 days, 21 hours.

3 First navigation by walking
The first person verified to have walked around the world was David Kunst. He walked 23,250 kilometres through four continents from 20 June 1970 to 5 October 1974.

4 Fastest solo wind-powered circumnavigation
This record of 42 days, 16 hours, 40 minutes and 35 seconds was established by François Gabart on 17 December 2017.

5 Circumnavigating the globe in a wheelchair
Rick Hansen covered over 40,000 kilometres – travelling through 34 countries in four continents – in a wheelchair from 21 March 1985 to 22 May 1987.

"Associated with kidnappings, the Gulf of Aden is nicknamed 'Pirate Alley'"

The jagged rocks of Cape Horn often combine with stormy weather to devastating effect

Inside the icebreakers

Ripping through frozen waters, these ships ensure safe passage through the thick ice of the Arctic Ocean

Cutting through the frozen waters of the world's coldest regions is no easy feat, especially for freight delivery or scientific exploration. Icebreaker ships have the important task of creating vital veins of infrastructure through the icy skin of the Northern Hemisphere. Typical freight ships seen across the world are often enormous pieces of mechanical engineering, but their ability to cruise through thick ice, however, is limited.

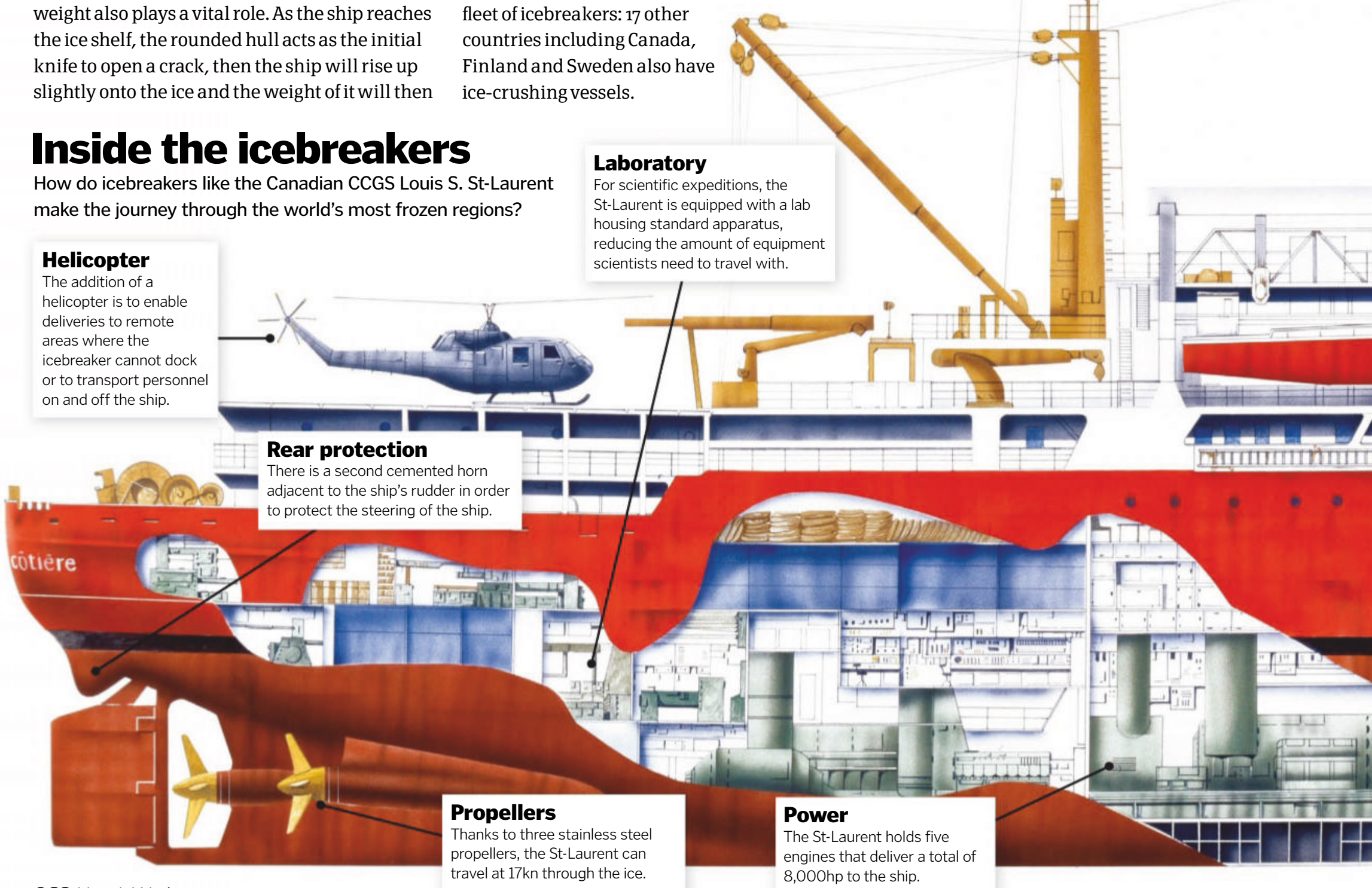
This has resulted in the creation of the icebreaker generation, using their specially designed hulls to part the ice, allowing safe passage for any freight following them through Arctic waters. These ships don't just break the ice like a sword slicing through the ice sheets: weight also plays a vital role. As the ship reaches the ice shelf, the rounded hull acts as the initial knife to open a crack, then the ship will rise up slightly onto the ice and the weight of it will then break the ice up. As the icebreaker's engines continue to propel the ship forward a channel through the ice is formed.

These ships are not a modern-day invention or one new to even the last century. In the mid-1860s the Pilot was the world's first steam-powered, metal-hulled icebreaker, built to sail through ice in Russia. Since then Russia has grown its fleet of icebreakers to the world's largest: 46 vessels and counting. This will include nuclear-powered ships Arktika and Sibir, poised to set sail in the coming years. These future icebreakers will house small nuclear reactors to produce enough energy to cut through around three metres of ice.

Of course, Russia isn't the only country with a fleet of icebreakers: 17 other countries including Canada, Finland and Sweden also have ice-crushing vessels.

Inside the icebreakers

How do icebreakers like the Canadian CCGS Louis S. St-Laurent make the journey through the world's most frozen regions?



Helicopter
The addition of a helicopter is to enable deliveries to remote areas where the icebreaker cannot dock or to transport personnel on and off the ship.

Laboratory
For scientific expeditions, the St-Laurent is equipped with a lab housing standard apparatus, reducing the amount of equipment scientists need to travel with.

Rear protection
There is a second cemented horn adjacent to the ship's rudder in order to protect the steering of the ship.

Propellers
Thanks to three stainless steel propellers, the St-Laurent can travel at 17kn through the ice.

Power
The St-Laurent holds five engines that deliver a total of 8,000hp to the ship.

Icebreakers are used for freight delivery and scientific exploration

Russia's Pilot ship was the first steam-powered metal ship to travel through ice

Underwater icebreakers

Though icebreakers on the surface of the water are successful in creating a safe passage, the task can be slow. Researchers at Komsomolsk-on-Amur State Technical University in Russia are developing a faster method of breaking ice from beneath it.

Using a method developed in the mid-1970s, the Russian research team is adapting the principle of resonance ice breaking – traditionally used by hovercraft to break ice – and applying it to submarines. This method involves utilising flexural gravity waves (vibrations produced by moving vehicles) to lift and split the ice. By travelling 20 metres below the ice, a submarine could break ice that is two metres thick.

By comparison, an icebreaker ship typically travelling at three knots would create a passage ten times slower. The new method is still in development and is not yet commercially used.

Submarines could be the future of icebreakers, cracking the ice from beneath the surface

Armour
To protect the ship from grazing ice, a 5cm-thick steel 'belt' surrounds the St-Laurent.

Bubble support
Brute force may not be enough to move ice, so to ease friction while crossing compressed air is pumped out from its sides at the hull under the waterline.

Hull and horn
Together these act as the ships 'knife' to cut through the ice. The hull's shape and the cement-filled horn allows the ship to break ice without mounting the ice sheet.

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FUTURE

Hydrogen-powered trains

Could hydrogen be the future power source for trains?

Earlier this year French rail vehicle manufacturers Alstom unveiled the world's first zero-carbon train totally powered by hydrogen fuel cells. This ingenious vehicle relies on electricity produced from rooftop hydrogen fuel cells to power a traction motor, which turns the wheels to move the train. Tanks that house the hydrogen can power the train for about 1,000 kilometres before requiring a refill.

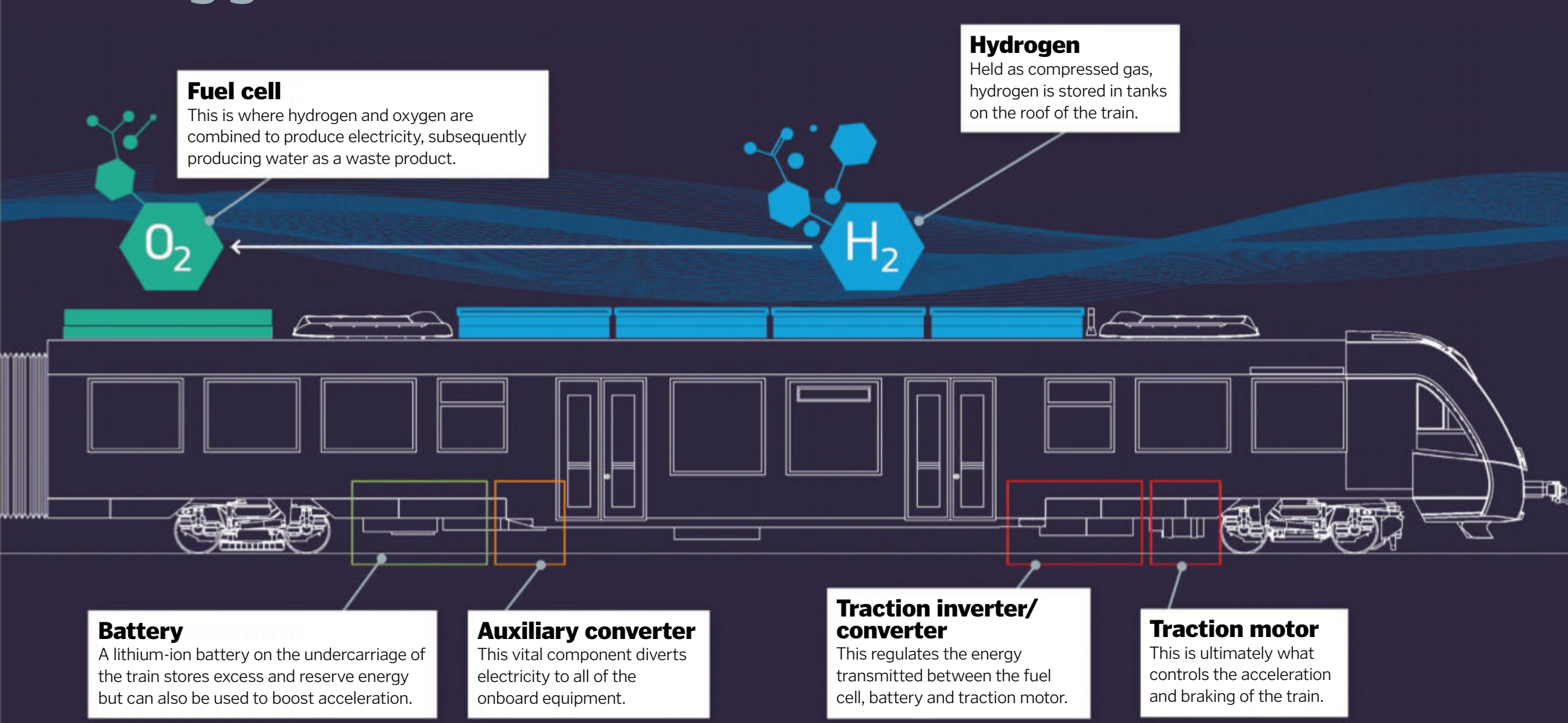
It was in 1839 when Sir William Robert Grove developed the principle of producing electricity from a electrochemical reaction between hydrogen and oxygen. However, due to the cost and low efficiency it has taken until the last few years for hydrogen to be a viable energy source for public transport, like the new Coradia iLint hydrogen train.

Now running services in Lower Saxony, Germany, the iLint has ditched the diesel and instead utilises hydrogen to propel its carriages at up to 140 kilometres per hour, equal to its fossil fuel alternatives.

Currently, a mobile station recharges the cells, however, there are plans for a stationary refill site to be in operation by 2021. This green method of energy production could be the future for trains in Germany, with Alstom proposing another 14 'hydrails' be introduced in Lower Saxony state by 2021.

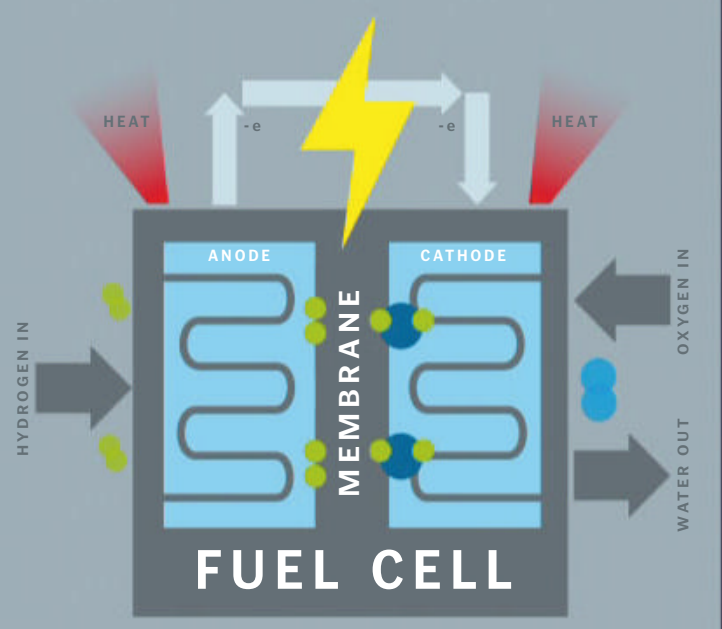
Going green

How does the iLint get people from A to B without leaving behind a carbon footprint?



Inside the cell

The process of obtaining energy via a hydrogen fuel cell is theoretically relatively simple. Compressed hydrogen gas is fed into the fuel cell, where it is met by the anode electrode. The anode separates the hydrogen's negatively charged electrons, leaving positively charged hydrogen ions (protons) behind. The electrons then flow through a circuit and produce an electric current for power (and heat). The hydrogen ions travel to the cathode side through the electrolyte membrane, which only allows certain types of ions through. This is where oxygen is fed into the fuel cell, where it combines with the electrons from the circuit and hydrogen ions to form water. The water is then drained away from the exhaust.



The Coradia iLint is completely emission-free, powered only by hydrogen and oxygen

THE FALL OF THE WINTER PALACE

This icon of imperial might was the setting of power struggles, assassination attempts and events that changed Russia forever

Words by **Jodie Tyley**

On 25 October 1917* an armed and angry mob of Bolshevik troops marched through the streets of Petrograd (now St Petersburg). Their target was the Winter Palace – the seat of the government they were determined to overthrow. A gun signalled the start of the assault that would become known as the October Revolution. The insurgents broke into the palace, ransacking and pillaging its riches (and wine cellar) until they found the ministers holding what would be their last ever meeting. With the communication lines dead, the government members had little choice but to surrender. More wine than blood was spilled that night, but it signalled the start of a brutal period in Russian history.

After 1917 the Winter Palace became a symbol of the 'people's revolution', but it had in fact started life as a statement of imperial power. For centuries the palace was the royal residence of the Russian emperors, or 'tsars', and it was reconstructed several times to accommodate their expensive tastes. The original palace was a humble wooden abode, built in 1703 for Peter the Great, the founder of the Russian Empire. He established the city of St Petersburg and chose this site on the banks of the River Neva as an area of strategic importance.

Peter's descendant Anna Ioannovna had an even grander vision. In 1731 she commissioned the great baroque architect Francesco Bartolomeo Rastrelli to build the Winter Palace. Years later, in 1754, Rastrelli would expand the building once again, this time under the orders of Elizabeth Petrovna, who had seized power the previous decade when she marched into the palace at the head of a regiment.

Elizabeth wanted to display her power with several grand ballrooms for court spectacles – but all that pomp and pageantry came at a price. The original budget of 859,555 rubles spiralled into 2,500,000 – paid for by increasing taxes on

A recreation of the storming of the Winter Palace in 1917 from the film *October* (1927)

taverns, salt and alcohol. This was at a time when Russia and its people were already stretched thin by the Seven Years' War (1756–1763). Labourers worked all year round, even in the bitter winters, but the project was not complete by the time of the Tsarina's death in 1761. When it was finished the following year, the architect said it was created "solely for the glory of Russia".

> *"The original palace was a humble wooden abode built in 1703"*

Unfortunately for Rastrelli, the building wasn't to Catherine the Great's liking. When she came to the throne baroque architecture and rococo decorations were no longer fashionable – Neoclassical was all the rage. It was a more austere approach to design, with columns and clean, elegant lines. Catherine quickly set about revamping the interiors of the Winter Palace, removing the gilded plaster and other adornments.

In 1764 the Tsarina built the Small Hermitage to entertain her friends and hold her newly acquired art collection. Catherine had purchased 225 paintings by masters including Rembrandt, Raphael, Holbein and Titian. This was the beginning of what is now one of the biggest and most prestigious art institutions in the world, the Hermitage Museum.

Long before it opened to the public, however, cats prowled the underbelly of the Hermitage. The felines had been a fixture of the palace since Elizabeth issued a decree that the 'best and biggest' rodent catchers were sent to court. Catherine once wrote, "My paintings are enjoyed only by myself and the mice." Today, the cats are almost as well known as the collections, surviving wars, invasion and the revolution. The priceless art also endured, despite a fire in 1837 that raged for three days. Scrambling to stop the flames spreading to the Hermitage, the passages that linked the buildings to the Palace were dismantled on the orders of Tsar Nicholas I.

Keen to cover up this monumental disaster, Nicholas ordered that restoration work begin immediately. Architects Vasily Stasov and Alexander Bryullov saw that the interiors were returned to their former glory. In particular, Nicholas demanded the state staircase and the Large and Small churches be 'restored exactly as it was'. Just 15 months later the royal family had moved back into the palace. However, its days as the official imperial residence were numbered.

Alexander II was the last Tsar to live at the Winter Palace – his assassination in 1881 had led

What's in a name? The many guises of the capital of Imperial Russia

St Petersburg, 1703
Peter the Great founded the port city in 1703, naming it in honour of Saint Peter the Apostle.

Petrograd, 1914
With the outbreak of WWI, the Russians felt the name sounded too German. 'Petro' honoured Peter the Great, while 'grad' was a common suffix of Russian cities.

Leningrad, 1924
Led by Vladimir Lenin, the Bolsheviks overthrew the monarchy, and the Soviet Union was created in 1922. The city was renamed Leningrad after the death of their former leader.

St Petersburg, 1991 – Present
After the fall of the USSR, citizens voted on whether to change the city's name. For some, it was a chance to reclaim their heritage after 70 years of brutal communist rule.

A Leningrad travel poster by B Zelensky

The Hermitage's cats guard the museum's artworks from mice

his family to believe the palace was not safe. One attempt on his life saw a bomb explode in the dining room, killing 11 guards. In the end he was attacked in the streets of St Petersburg by revolutionaries and carried back, bleeding and broken, to the palace by sleigh. He died in his study, where decades earlier he had signed the Emancipation Reform of 1861, granting more than 23 million people their freedom. However, his reforms weren't enough to change the minds of the people, who were turning against the monarchy in their droves.

In 1905, this came to a crashing crescendo when thousands of unarmed demonstrators marched towards the Winter Palace to petition for better working conditions in the factories. It was a peaceful protest that ended in tragedy. The Imperial Guard unleashed fire and killed hundreds of people in Palace Square – an event that became known as Bloody Sunday.

Discontent among the population escalated rapidly, particularly during WWI, a conflict in which Russia was allied with France and Britain against Germany and the Austro-Hungarian Empire and one the Russians were losing. In 1915 the Winter Palace had been cleared of its treasured possessions and transformed into a busy military hospital. The lavish state rooms and halls with their gilded columns became operating theatres, medical store rooms and wards.

Beyond the palace walls, widespread demonstrations had begun in the city. The army had turned against the Tsar, leaving Nicholas II no choice but to abdicate with his family in 1917, ending 300 years of Romanov rule (a fact brutally confirmed by the family's execution in 1918).

A weak provisional government was established at the Winter Palace until it too was overthrown. The premises were then used as a museum of the revolution, and though the palace's rooms have since been restored to their former imperial splendour, it has been open to the public ever since.

*According to the Eastern calendar that was used in Russia at the time. The October Revolution took place on 7 November on the Western (Gregorian) calendar.

After the fire, architect Vasily Stasov was ordered to restore the staircase to its original design

Military Gallery of 1812
The gallery commemorates Russia's victory over Napoleonic France and displays 332 portraits of generals who fought in the War of 1812.

Small Throne Room
A silver-gilt English throne from 1731 resides here in this room dedicated to Peter the Great.

Jordan Staircase
Here, the Tsar watched the ceremony of the 'Blessing of the Waters' of the Neva River to celebrate Christ's baptism in the Jordan River.

Field Marshals' Hall
The great fire of 1837 began in this wooden hall and spread throughout the palace.

Peek inside the palace

Explore just some of the 1,057 rooms of the former royal residence

Nicholas Hall
The largest room in the palace was the setting of imperial balls and ceremonies. It was named after Nicholas I following his death in 1855.

Malachite Room
This state drawing-room from 1839 is decorated with over 2tn of malachite – a green copper mineral from Russia's Ural Mountains.

Royalty to revolution

The Palace has witnessed many key moments

1703 A wooden cabin belonging to Peter the Great originally stood on the site of the Winter Palace.

1711 The royal residence is replaced by a stone building.

1731 Peter's descendent Anna Ioannovna commissions Italian architect Rastrelli to design a larger complex.

1754 Tsarina Elizabeth Petrovna orders Rastrelli to expand the palace once again.

1762 Catherine the Great takes the throne and makes her own mark on the interior décor.

1837 A devastating fire breaks out on 17 December and rages for three days.

1844 Tsar Nicholas I decrees that buildings in St Petersburg cannot be taller than the palace.

1881 After the assassination of Alexander II the palace ceases to be a royal residence.

1903 A grand ball is held to celebrate the 290th anniversary of the Romanov dynasty – the last ball of Tsarist Russia.

Armorial Hall
Originally intended for grand receptions, this room became a military hospital during WWI.

"Alexander II was the last Tsar to live at the Winter Palace"

The dining room of the Winter Palace after a bomb exploded in 1880

The White Hall
Created for the wedding of the future Alexander II in 1841, this hall formed part of the private rooms of the Tsar and Tsarina after the ascension.

Gothic Library
Designed in the Victorian Gothic style, this vast library was part of the private apartments of the last Tsar of Russia.

Palace façade
The exterior was painted turquoise in the 1940s. Originally the walls were a sandy colour, then dark red in the 1900s and orange in the 1920s.

Gold Drawing Room
This gilded room was reconstructed after the fire of 1837 and is located in the apartments of Tsarina Maria Alexandrovna, wife of Alexander II.

A portrait of the Hermitage's founder, Catherine the Great, hangs in the museum

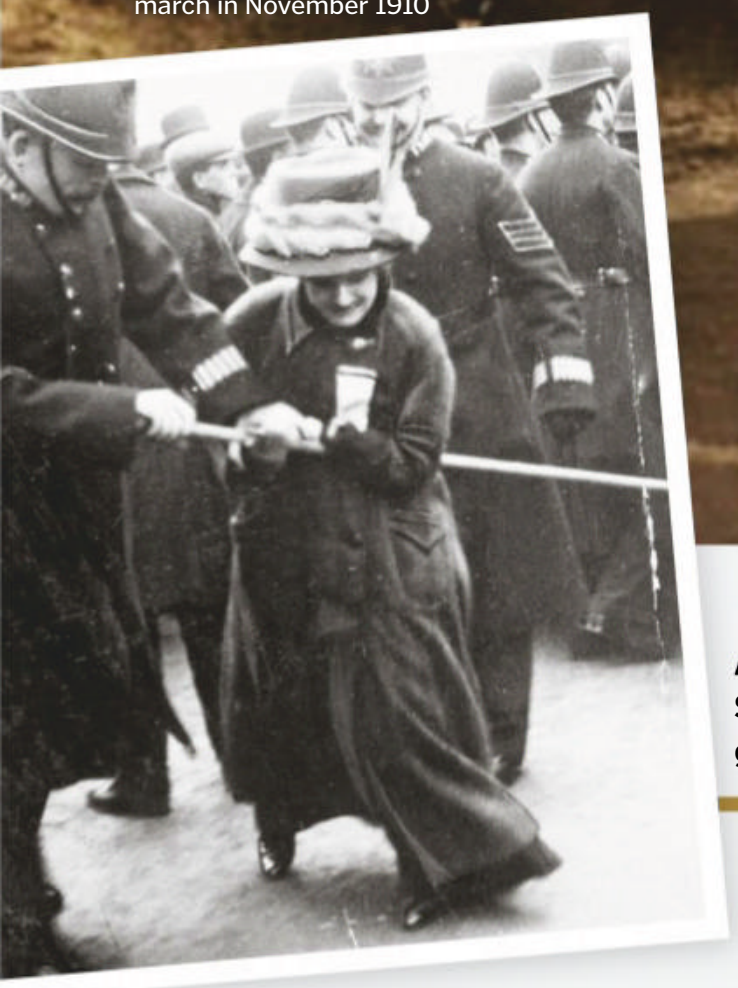
1915
Empty state rooms are transformed into hospital wards for WWI soldiers. The museum's collection is sent to Moscow for safety.

1917
The palace is declared part of the State Hermitage Museum following its capture by the Bolsheviks.

1940s
The German's ruthless siege of Leningrad (1941–1944) leaves the palace in ruins. Restoration work begins once it's lifted.

Sophia selling copies of *The Suffragette* newspaper outside her home at Hampton Court

A female protestor struggles with a policeman during the Black Friday march in November 1910



A life's work

Sophia lived through a period of great social and political upheaval

1876
Sophia is born in Suffolk to Maharaja Duleep Singh and Maharani Bamba Duleep Singh.

1886
Sophia's family are detained in Aden after her father tries to return to India to reclaim control of the Sikh Empire.

1895
Sophia and her sisters are invited to Buckingham Palace by Queen Victoria and are presented at the debutante's ball.

1903
Travelling to India, she witnesses the oppression, poverty and horrific treatment of the people.

Sophia Duleep Singh

This princess of a stolen empire became one of Britain's most high-profile women's rights activists

Born and raised in England, Sophia was the daughter of Maharaja Duleep Singh, the exiled Emperor of the Sikh Empire and a favourite courtier of her godmother, Queen Victoria. She was brought up among the British aristocracy and enjoyed all the luxuries of royalty, wearing the latest fashionable dresses to all the exclusive parties. After the death of their parents Sophia and her sisters were granted apartments at Hampton Court Palace by the queen, as well as an annual income of £25,000. However, this pampered princess was soon to encounter severe inequality and discrimination on account of her gender and race.

In 1903, Sophia visited India to attend celebrations for Edward VII's coronation as king and emperor. It was during this and subsequent trips that she became more aware not only of her own heritage and ancestry but also of Britain's oppressive colonial rule. She and her sisters also experienced racist and prejudiced attitudes that were prevalent at the time.

Despite their royal status, they found themselves snubbed and shunned at social events, or even ridiculed and criticised for wearing traditional Indian dress. She may have been the descendent of maharajas and Queen Victoria's goddaughter, but Sophia was made to feel like an outsider in the very region her family had once ruled.

After her return to England, Sophia became heavily involved in the women's suffrage movement. She supported the campaign to gain women the vote, donating money to the cause and even selling copies of *The Suffragette* newspaper outside her residence at Hampton Court. On 18 November 1910 she joined hundreds of other protestors in a march on Parliament, demanding that a law be passed granting women the vote. The day was later referred to as 'Black Friday' after scores of marchers were violently assaulted by police, scenes to which Sophia was an appalled witness.

Despite alienating some of her aristocratic friends, Sophia continued her activism, supporting the Women's Social and Political Union (WSPU) and its leader Emmeline Pankhurst. Although many fellow suffragettes were sent to jail for their activities, Sophia's status meant the authorities were reluctant to imprison her.

Sophia continued her work with the movement until the outbreak of WWI in 1914, when the WSPU suspended its activities to support the war effort. After the war she maintained her fight for women's rights, claiming in a 1934 article that her sole interest was "the advancement of women".

After largely retiring from public life she remained unmarried and without children. The revolutionary royal who had fought so hard for the betterment of those less fortunate than herself died of cardiac arrest at her home in Wycombe, Buckinghamshire, in August 1948.

THE BIG IDEA

As part of her activism, the princess joined the Women's Tax Resistance League

The Women's Tax Resistance League (WTRL) was a protest group that refused to pay taxes while women were not allowed to vote. Their message was simple: 'No Vote, No Tax'. Several members of the group were prosecuted as a result, including Princess Sophia, who was one of the group's high-profile members from 1909. In 1911 she was brought before a court and fined. Several pieces of her jewellery were confiscated and sold to pay for the debt. However, Sophia's fellow WTRL members purchased the jewellery and returned them to the princess.

This WRTL banner features MP John Hampden, who refused to pay tax under similar circumstances

5 THINGS TO KNOW ABOUT... PRINCESS SOPHIA

1 A royal godmother
After arriving in Britain, Sophia's father Maharaja Duleep Singh became a favourite of Queen Victoria, and later she became godmother to his children.

2 Revolutionary activist
A committed member of the Women's Social and Political Union (WSPU), Sophia took part in several marches and protests – she even once hurled herself onto Prime Minister Herbert Asquith's car.

3 Answering the call
During WWI Sophia suspended her activism and volunteered to become a nurse. She treated Indian troops, many of them astounded by her royal ancestry.

4 A Punjabi princess
Although she was raised among the English aristocracy, Sophia's father was the last Maharaja of the Sikh Empire. The British deposed him after the empire's annexation in 1849.

5 Crisis of faith
Although she had been raised a Christian, later in life Sophia reconnected with her Sikh origins, requesting her ashes be scattered in India in her will.

1914–18
Volunteering to work as a nurse during WWI, she treats wounded Indian soldiers recovering at Brighton Pavilion.

1910
On 18 November, Sophia takes part in demonstrations outside Parliament, demanding women's rights – later known as Black Friday.

1948
Sophia dies at her home in Wycombe, Buckinghamshire. According to her wishes, her body is cremated in Sikh tradition.

1915
She takes part in the 'Women's War Pageant' to promote women's contribution to the war effort, an event organised by Emmeline Pankhurst.

Sophia's father, Maharaja Duleep Singh in ceremonial dress, 1861

Titanic rhino ancestors

What it lacked in weaponry the Paraceratherium made up for in sheer size

Appearing over the horizon or emerging from a patch of trees, Paraceratherium would be an intimidating and somewhat confusing sight to a modern observer: with the height of a dinosaur and the leathery skin of an elephant, it wouldn't be immediately apparent what these creatures were.

Paraceratherium, scientists now know, was a genus of giant rhino. The group contained towering beasts standing almost five metres tall at the shoulder and potentially weighing 20,000 kilograms. Its members lived across Eurasia during the Oligocene epoch, between 34 and 23 million years ago, and were so far back in the branches of the rhino family tree that they predate the evolution of the facial horn.

Paraceratherium's exact height isn't agreed on because the fossils that form our knowledge of the genus are incomplete, but with its estimated size it's a strong contender for the title of largest land mammal ever. While rhinos today are more compact, Paraceratherium's legs and neck were relatively long. This impressive body allowed the rhinos to browse tall trees and navigate huge ranges in search of food and mates. To grab hold of foliage, it had a muscular top lip or perhaps even a proboscis like a tapir. Unlike their solitary modern relatives, it's thought that females and their calves travelled and lived together in small herds.

Despite its size, Paraceratherium was not invincible. Bite marks on fossils suggest that some young and ill animals fell victim to enormous crocodiles, and the entire genus went extinct after about 11 million years on Earth. Elephant-like animals emerging on Eurasia could have reduced the food available to the rhinos by destroying areas of forest, and large predators moving north from Africa may have been able to prey on Paraceratherium calves. The cause of their extinction is unknown, but it's likely that several factors contributed to the downfall of this graceful giant.

Hefty head
Supported by a long neck, Paraceratherium's skull was about 1.3m long.

Bare face
Unlike its modern relatives, this rhino lacked any sort of facial horn.

Good grip
The shape of the skull suggests the giant had a large prehensile top lip or proboscis.

Grasping teeth
A pair of large incisors in each jaw probably helped to hold branches steady during feeding.

Herd life
Experts believe the rhinos lived in small herds with social structures similar to elephants.

Why can't mammals just keep growing?

Of the largest known land animals, many were reptiles. Mammals spend about ten per cent of their energy on maintaining body temperature, so there's less available for growth. Energy is one of the biggest limiters of size – larger bodies require more fuel, something that a Paraceratherium would find hard to come by in our crowded world.

Even given sufficient food, animals couldn't just keep evolving bigger bodies. As size increases mass goes up at a greater rate than bone size and muscle strength, so there would come a point where an evolving mammal risked collapsing under its own weight.

Developing thicker limbs and bones might help, but the chunky giant would struggle to meet an even greater need for food with its ungainly movement. As well as movement, development and reproduction tend to be slower in larger animals so they're at greater risk of extinction when conditions change.

Weighing approximately 5,000 kilograms, the elephant is the largest remaining land mammal

"Despite its size, Paraceratherium was not invincible"

Large but little-known

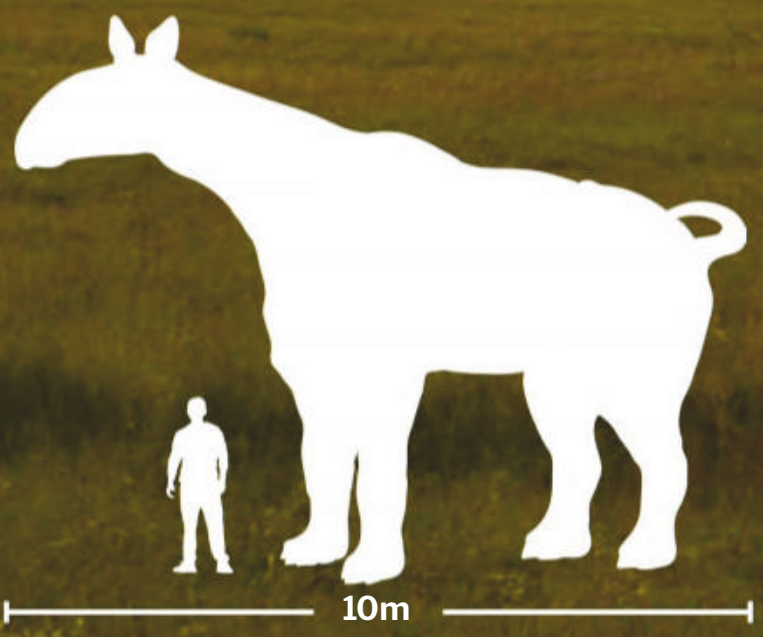
Relatively little is known about Paraceratherium. The first fossils now recognised as belonging to the genus were collected in Balochistan (modern-day Pakistan) in 1907–1908 by a British geologist. Other fossils began to turn up across Asia but political unrest and global conflict meant that collaboration on research into an extinct rhino genus wasn't exactly a priority, so discoveries were published in local languages and not shared. The correct taxonomy of members of Paraceratherium and their close relatives is still debated, and the fact that a complete skeleton is yet to be discovered means scientists continue to argue about what exactly these prehistoric rhinos would have looked like.

Tail?
A complete fossilised spine is yet to be found, so the presence of a tail is pure speculation.

Living it large
Modern rhinos probably wouldn't recognise their ancestors

Little hair
Being largely hairless would have stopped the giant rhino from overheating.

Pillar-like legs
For such a large animal, Paraceratherium had surprisingly long and slender legs.



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The strange sound of didgeridoos

Forged by nature and steeped in tradition, the didgeridoo is a triumphant symbol of Indigenous Australian culture

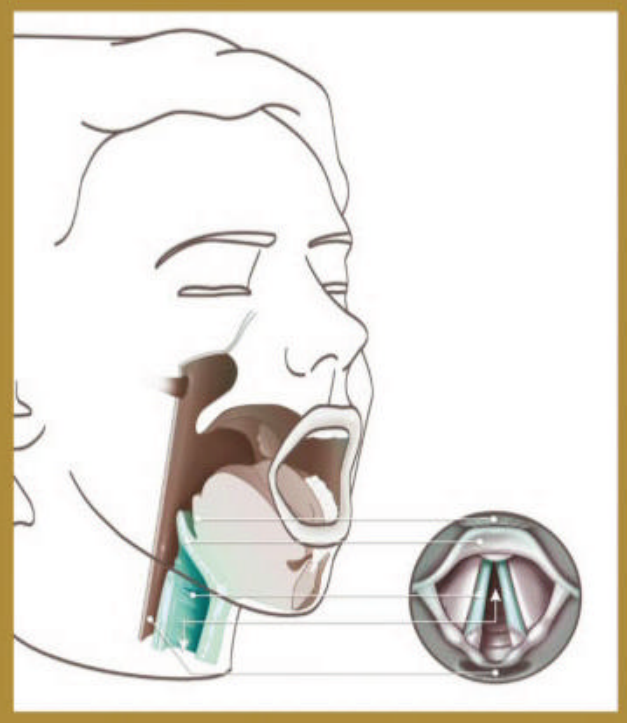
If there is one musical instrument that instantly evokes an image of a country, then it is the didgeridoo. The instrument may well have been embraced worldwide and featured in all manner of music genres, but the gnarly and messy-looking traditional didgeridoo will be forever remembered as an Australian invention.

The didgeridoo is widely believed to be one of the world's oldest instruments, with some educated guesses placing its origins back to Australian natives 40,000 years ago. Tradition states that ancient tribes would use the didgeridoo's versatile sound to tell stories and orchestrate dances. Players would perform without pause for hours using a technique known as circular breathing, punctuating the consistent drone with yelps and grunts that would reverberate and boom from the instrument. So entrenched is the didgeridoo to native culture that even their mythological gods embraced the instrument's unique sound for their dance as they built the world.

If the didgeridoo was around when nature was created, then it is only fitting to learn that the instrument is hand-carved by nature itself. The traditional wood of the instrument is the eucalyptus tree, which often plays host to termites. Unfortunately for the plant the insects feast on its trunk from the inside out, hollowing them and leaving holes that puncture the exterior. But through their feeding the termites sculpt an instrument. All humans must do is find the right tree, chop it to the correct length and tighten the blowhole. Then they're ready to play.

The didgeridoo's unique drone

Like many brass instruments, including the tuba and trombone, the didgeridoo relies heavily on the player's vibrating lips to produce sound. But the didgeridoo has an additional, fascinating element to its sound. When the player is blowing into the tube, the produced sound waves flow into the instrument but also backward into the player's vocal tract. Inside the vocal tract some frequencies are muted and others resonated depending on the position of the tongue and overall shape of the tract. A similar pattern occurs within the instrument's cavity as some frequencies are enhanced while others are lost depending on the curves of the instrument. Thus this dual-sound-producing instrument is able to achieve an impressive range.



Didgeridoo players rely on their vocal tracts to resonate sound waves produced by the instrument

Inside an ancient instrument

Burrow into the organic origins and interesting sounds of the world's oldest wind instrument

Feeding time
Termites happily feed on cellulose within a eucalyptus tree, hollowing out the inside of the plant.

Knocking on wood
Didgeridoo makers can determine if a tree is hollow by simply knocking on the trunk.

From plant to instrument
After the branches and leaves have been stripped, the tree is cut to the appropriate length of 1.2–1.5m.

Sealing the blowhole
Hot wax can be used to narrow and seal the periphery of the blowhole to minimise sound loss.

Unique frequencies
The natural shape of the didgeridoo will result in some sound frequencies being stifled while others are amplified, producing an eclectic series of sounds.

Step 1: circular breathing
When their lungs are saturated with air, the player will exhale as normal.

Step 2: Puffing up
As their breath begins to wane, the player will puff their cheeks full of air and seal off the back of their mouth.

Step 3: Inhale
The player can now inhale through their nose while maintaining the exhalation of air stored in their cheeks.

Discover: Lands Unknown

Do what you can to stay alive and escape this mysterious land

■ Publisher: **Fantasy Flight** ■ Price: **£57.99 ($59.95)** ■ Number of players: **1–4** ■ Recommended age: **12+** ■ Typical game time: **60–120 mins**

The aim of your strategy is simple: stay alive, explore the map and complete your challenges. The game plays rounds in the form of days, with each day posing different obstacles and challenges that form a story. Every copy of the game is different, containing an assortment of parts that are individual to your set. This produces a unique experience to your version of the game. Each game comprises two of six map terrains and 12 out of 36 characters, which have their own special abilities.

During play you have four hearts. These can be lost due to four inflictions: physical damage, dehydration, starvation and poisoning. Once all hearts are gone you are out of the game. A survivor takes their turn using stamina points. You trade one point for every action and at the end of a turn your stamina is replenished - often generously, so don't hesitate to use them.

During the day (a turn) you need to collect resource tokens and explore the map. Your objective here should be to work together with the other survivors to reveal the map, find resources and complete projects. You start the game with a project each and can find more during the game. Projects enable you to build tools that will improve your character's abilities and make the challenges easier. Helping each other expedites this, creating more possibilities for your survival. Projects, once completed by the original owner, become open to everyone, an aspect you can take advantage of.

Your survivor needs to eat and drink, making it necessary for you to find resources. Water sources, once found, can be returned to for collection. Gathering food, however, often requires you to fight, kill and cook animals. This can be a lengthy process, and with time limiting the game there's an urgency for your character to be capable of handling these tasks as soon as possible. In most cases gathering food puts your survivor in danger of losing hearts.

At the end of a turn a player draws a night card, which affects everyone. These cause the players to discard and/or consume resources, possibly inflicting heart loss. Night cards can also summon animals, so it's ideal to be near a campfire at this point/end of your turn.

Terrain book
Each game has two terrains and every copy of *Discover: Lands Unknown* is different. These rulebooks explain how to lay out the map.

Character cards
At the beginning of the game you are randomly given two cards from the character deck to choose from. These characters have special abilities that can help you during the game, although you may never need them.

Player dial
This allows you to keep track of your hearts and your stamina.

Landmarks
These are illustrations on the map that portray numbers relating to exploration cards. They progress the story of the game.

Tribe leader token
This token decides who goes first and then the order proceeds clockwise. At the end of a day a new leader can be elected. This comes with the advantage of going first but has disadvantages regarding other cards.

A bountiful land?

Look for resources and make sure you're safe by nightfall

Resource tokens
These represent the materials you collect during the game while investigating feature tokens (see Feature tokens).

Exploration card & enemy cards
These cards are the challenges and events that happen throughout the game. The numbers in the top left are used as identifiers so that they remain a mystery until played.

Feature tokens
These are placed on the board and indicate a possible resource location. That resource is marked on the token in the corner, which allows you to actively play for what you need.

Night cards
Split into two colours, night cards indicate a challenge rating. You start with four blue cards that are easier then progress to red cards that are more difficult challenges.

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Who's answering your questions this month?


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JO STASS

Why does it take so long to reach Mercury?

Edward Langley

On its closest approach, Mars lies 57.6 million kilometres from Earth and takes a probe six months to reach. Mercury, however, is 77 million kilometres away on its closest approach and yet it will take BepiColombo over seven years to reach it. Why the discrepancy? The Sun. As probes travelling to Mars need only worry about the Sun slowing their escape, probes moving toward the gravitational centre of our Solar System must concern themselves with over accelerating. Even though Mercury is very small and moves very quickly, the probe would whizz right by the planet if we were to shoot it straight at Mercury from Earth. To avoid this, the probe will 'slingshot' around other planets, controlling the acceleration and correcting its course but adding time onto the journey. **JH**

As Mercury is small and close to the Sun, getting captured in its orbit is difficult

Want answers?

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What is a quokka?

Lilly Wakefield

Like their kangaroo cousins, quokkas are marsupial mammals native to Australia. Although they have sadly been mostly eradicated from the mainland, around 10,000 quokkas still thrive on Rottnest Island off Australia's western coast. Resembling a mini kangaroo with a long, rat-like tail, quokkas have garnered a reputation for being curious and friendly little critters. **JH**

The follicle phenomenon is caused by a variation of the MC1R gene

Why do some men grow ginger beards when they don't have red hair?

Karl Jones

The reason why hair colour can vary in different parts of the body is because of the variety of ways genes can express themselves. Many genes are responsible for determining hair colour, but one in particular plays a crucial role in giving people red hair: the MC1R gene. We all have it, but when someone inherits a mutated version from each parent they will have red hair and fair skin. Inherit just one mutated MC1R gene, however, and red hair can appear in random places, like beards. **JT**

How do pet-calming plug-ins work?

Sara Newman

Pet-calming plug-ins work by releasing pheromones, chemical substances that our pets release naturally. These are odourless and therefore undetectable to humans, but our pets are able to sniff them out easily. Cats release pheromones from various parts of their body (including their cheeks and paws) to either remind them an object is familiar and safe, send other cats a message to keep out of their territory, or to calm their kittens. Meanwhile, dogs release pheromones from their mammary glands to help their puppies feel secure. Plug-ins replicate these pheromones to provide comfort to our pets, helping to relax them and prevent any unwanted behaviours. **JS**

Plug-ins can help our pets to be happy and relaxed

How were Neil Armstrong's first steps on the Moon filmed?

Louis Redmond

In the Lunar Module's descent stage, a camera was stowed to the left of the ladder. When Armstrong opened the module door, he pulled a lanyard that unfolded the filming equipment and Buzz Aldrin hit a circuit breaker that turned the camera on and captured the historic moment. The signal was then sent from the Lunar Module's antenna to tracking stations in Australia, where it was converted into broadcast format and transmitted around the world. **JS**

Neil Armstrong after climbing down the Lunar Module ladder onto the Moon

Why is it easier to learn languages when we are young?

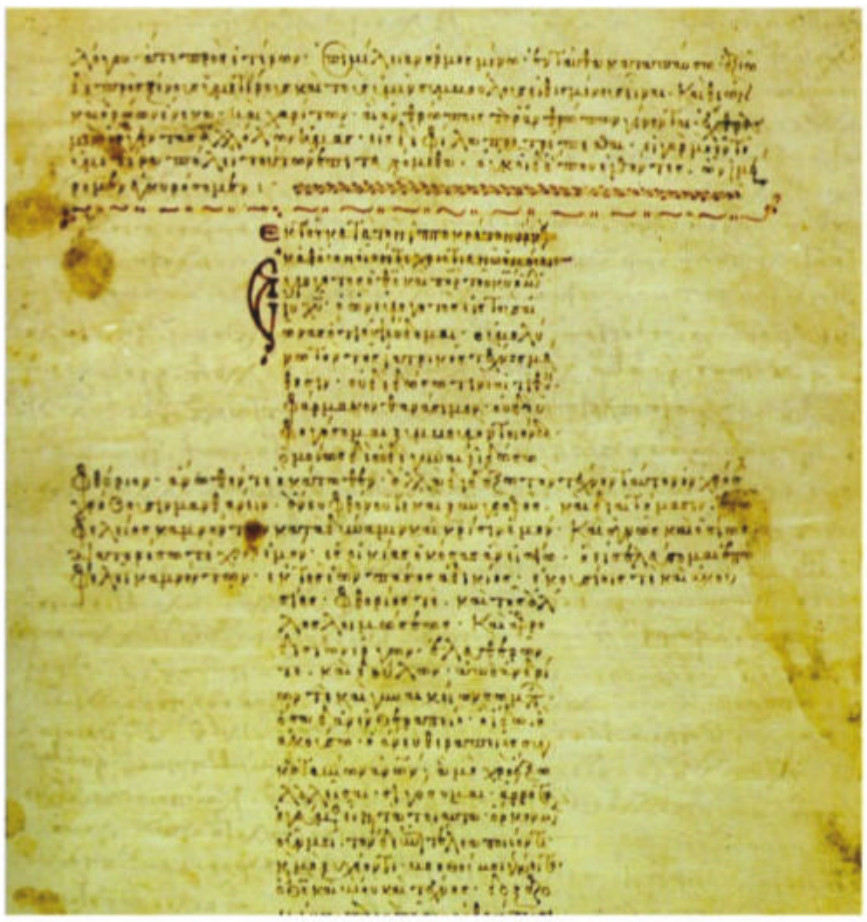
Hannah King

According to recent research, the best time to start learning a language is before the age of ten. There are three reasons for this. First, children have more time to learn. Second, the grammar of the first language you learn affects the way you learn other languages. Third, the brain trims connections as we age, making learning easier when we're young. **LM**

What is the Dunning-Kruger effect?

Jacob Riley

It's a psychological phenomenon whereby people with low ability or expertise fail to recognise their own shortcomings. Instead they feel over-confident in their performance and capabilities. This form of cognitive bias was identified in Kruger and Dunning's 1999 study. **JT**



What is the Hippocratic Oath?

Rupert Granger

■ The Hippocratic Oath has its origins in ancient Greece but is still used in various forms today. Mainly recited by newly qualified physicians, the Oath reminds doctors of their duty to patients. **JH**

Twinned towns were established to foster peace and understanding across the world

Where did the idea of twinning towns come from?

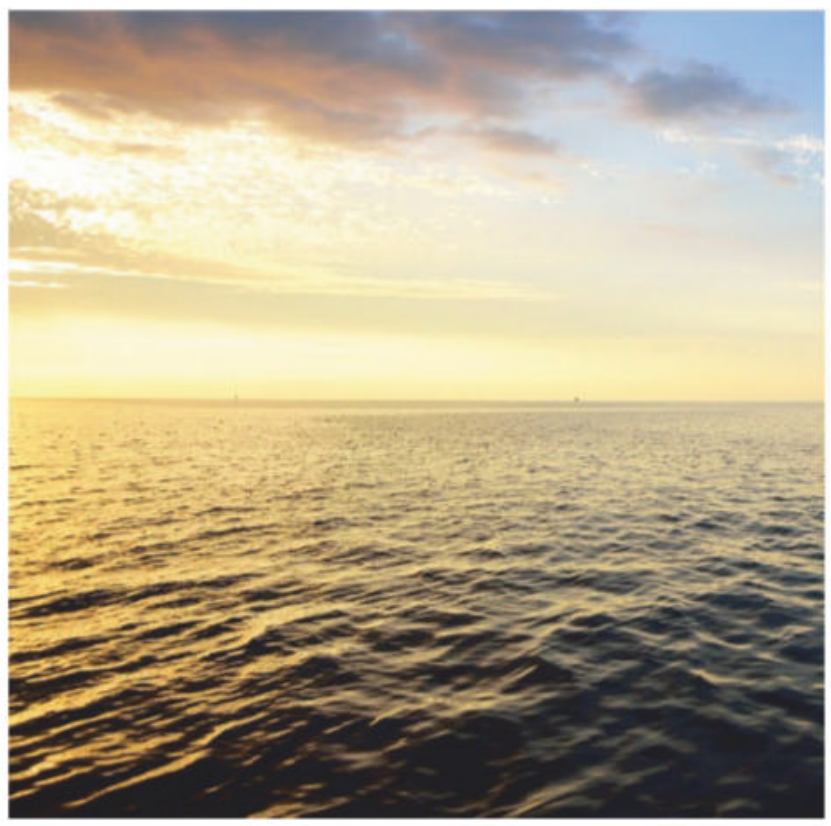
Ben Reed

■ Twinning is a partnership between two communities, ranging from villages and towns to cities and counties. The movement began after WWII to encourage peace and understanding, and it was promoted by the Council of European Municipalities (established in 1951). Twinning isn't limited to the European Union, but it has been used to help integrate new territories as they prepared to join, such as Greece, Spain and Portugal. Partners will sign a 'twinning oath' that outlines the long-term commitment to maintaining ties between governments and encouraging exchanges between citizens. It's not legally binding though, and the content can be adapted. **JT**

How did Hannibal cross the Alps with elephants?

Mohammed Nazir

■ During his war with Rome, the ancient sources say that Hannibal marched his army across the Alps in just 16 days with 37 war elephants in tow. Some historians believe that Hannibal used a smaller species of African elephant, which would have fared better through the narrow passes, but still would have needed 100 kilograms of feed each day. Some of the beasts may have perished during the crossing, but we know from later accounts of Hannibal's army that war elephants played a role at the vanguard of his army, terrifying the Romans on the other side of the field. **JH**



What's the difference between a sea and an ocean?

Helen Richards

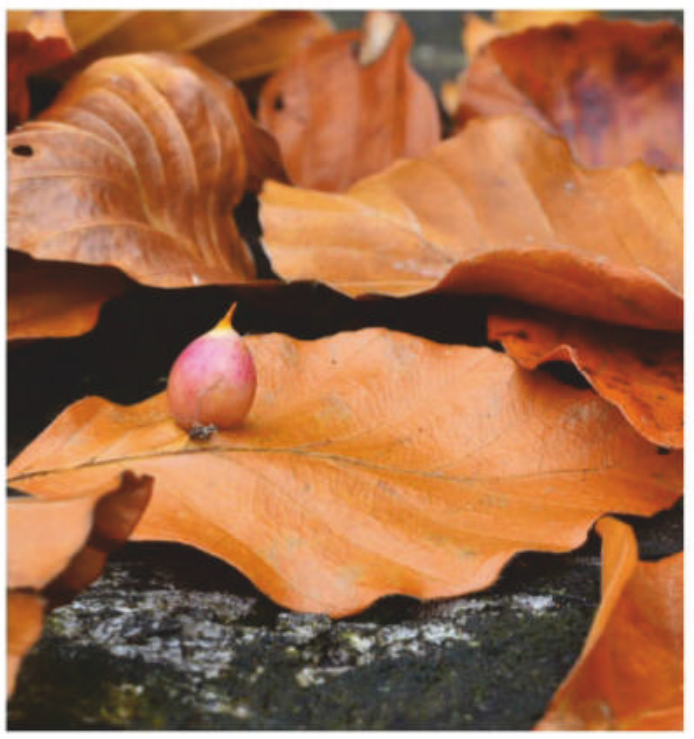
■ Sea waters are shallower and smaller than oceans, as they're usually partially enclosed by land. The deepest is the Caribbean Sea at around 6,946 metres, which pales in comparison to the deepest ocean, the Pacific, at 10,924 metres. **JT**

BRAIN DUMP

Is the interstellar object 'Oumuamua an asteroid or a comet?

Mark Brooks

It's hotly debated. It's shiny, like ice, and its path through space suggests it's releasing gas, like a comet. But we can't see any gas, so it might be an asteroid. **LM**

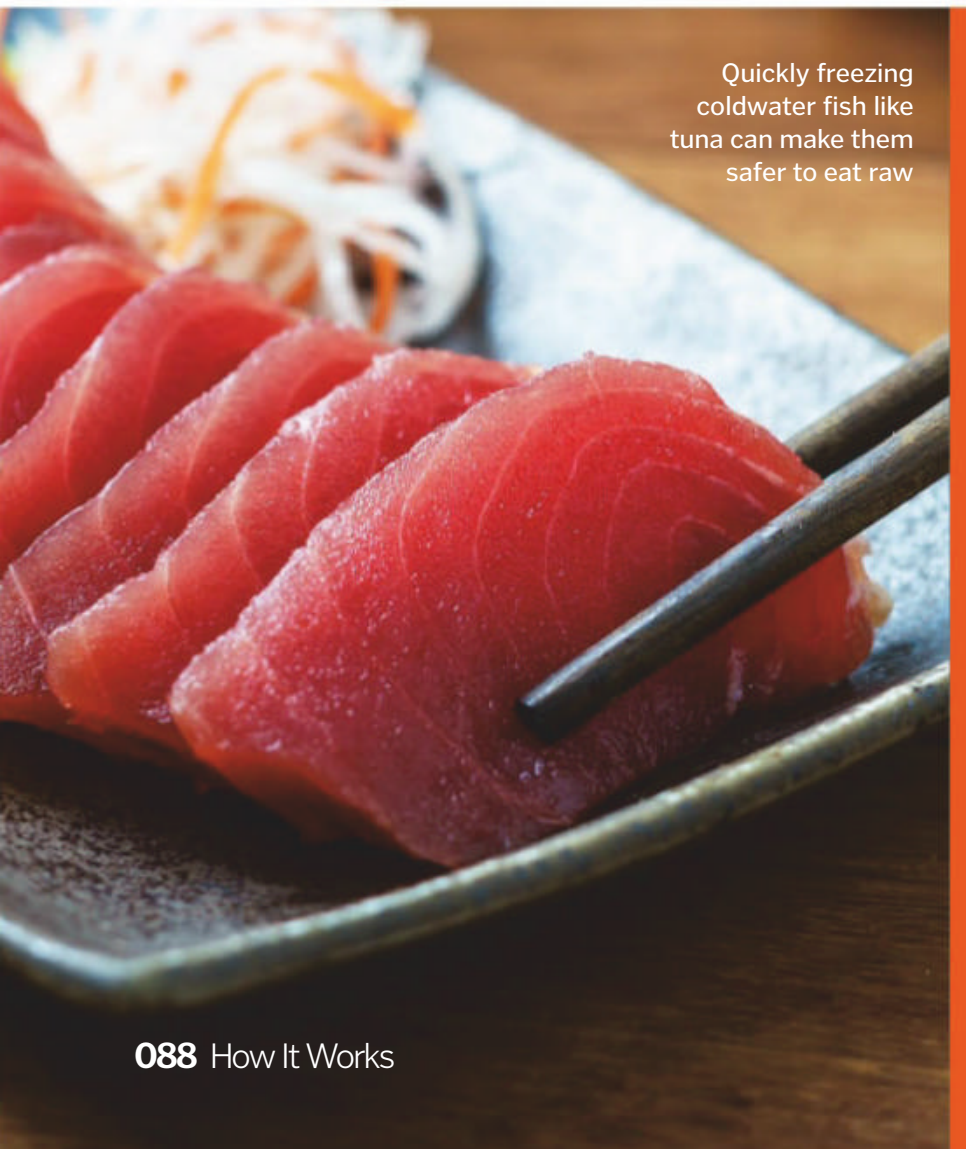


Plant tumours are known as galls. They don't spread like cancer

Do plants get cancer?

Jemima Blooms

Cancer happens when healthy cells lose control; they make hundreds of copies of themselves, piling together to form tumours. Cells at the edges of the tumours start to invade into the surrounding tissue until some manage to break free and spread around the body. This is what makes cancer deadly. Plant cells can form tumours too. When plants get particular infections it can change the way their cells work, making them start to divide out of control, but it's not quite the same as cancer. Plant cells are surrounded by a cell wall, which stops them moving around. So even when tumours start to form they can't spread. **LM**



Quickly freezing coldwater fish like tuna can make them safer to eat raw

How come we can eat raw fish (ie sushi) and beef (ie carpaccio) but not other meats?

Eduardo Raffaele

Like us, animals carry microbes, most of which live on the skin or in the digestive system. Whole cuts of beef tend to be safe to eat rare because their muscles are large and the inside doesn't come into contact with their guts or skin. But with smaller animals like chickens the chance of contamination is high. Fish carry different microbes, and, although they are small, freezing them helps to kill their parasites before they get to the table. **LM**

Why is chalk used on snooker cues?

Anish Khan

Snooker balls and cue tips are very smooth. Chalk adds friction, so when the cue tip hits the ball it is less likely to slip and spoil your shot. **TL**

Why isn't Japan allowed to have its own army?

Digby Huggs

After its defeat in WWII, Japan's new constitution banned it from having military forces that could attack other countries. Later, Japan was allowed to have a self-defence military force to protect itself, but not one that could threaten others. Today, the Japanese Self-Defense Force has thousands of soldiers, but it still has many restrictions on how they can be used and the sorts of weapons they are allowed, which stop it being a 'proper' army. **TL**

Japan has thousands of soldiers, but it doesn't technically have an army

What is the oldest tree?

Bee Barlow

■ The oldest living tree is a Great Basin bristlecone pine (*Pinus longaeva*) which can be found in California's White Mountains. It is believed to be over 5,060 years old! **JS**

Want answers?

Send your questions to...

How It Works magazine
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Do submarines have escape pods built in?

Victoria Smart

■ Very few submarines have been fitted with escape pods, but if people are trapped in a sunken submarine there are other ways of getting them out safely. Some navies have special mini-submarines that are small enough to fit aboard an aeroplane. These can be quickly flown to a sunken submarine and used to rescue the crew. As a last resort, submarines also carry inflatable escape suits that people can wear to float up to the surface from an airlock. The escape suits also act as a one-person lifeboat once they surface and will keep a person warm until rescue. **TL**

© Getty; ESO/M. Kornmesser

Submariners can escape sunken submarines wearing inflatable escape suits that also act as life rafts

Why aren't almonds and avocados vegan?

Lucy Greene

■ Many fruits and vegetables, including avocados and almonds, are not strictly vegan because they rely on migratory bee keeping. As the crops are difficult to grow naturally, bees are transported long distances by road to pollinate them. This unnatural use of animals means that many people don't regard them as vegan. **JS**

Does the Moon rotate?

Li Wei

■ The Moon does rotate, but we can't see that from Earth. It takes about 27 days for the Moon to fully rotate. It also takes about 27 days for the Moon to orbit the Earth. As the two are synchronised we always see the same side of the Moon from Earth. **TL**

BOOK REVIEWS

The latest releases for curious minds

True or Poo?

Filthy facts and falsehoods exposed

- Author: **Dani Rabaiotti & Nick Caruso**
- Publisher: **Quercus**
- Price: **£9.99 / $16**
- Release date: **Out now**

We love the idea of this book. There are plenty of myths about animals that people widely believe, and many of them are completely false. For example, the book tells us that touching a baby bird will not instantly cause its parents to abandon it. It will, however, be distressing for both the bird and its parents, so it's probably best to leave it where it is and not poke around in nests.

The book starts slowly, giving you facts that you've probably seen or heard about on a recent nature documentary. Thankfully, it soon hits its stride, with a mix of common misconceptions and almost unheard-of facts giving us plenty to keep us interested.

Personally, we'd never read that horses can't vomit, or that some frogs raise their young in their stomachs. Still, we now know that both of these facts are true, and each is presented with a fun breakdown of why. All of the facts presented within this book are well written, with a hint of humour to keep it light and entertaining.

There are times when the topics do dip back into myths that you already know to be false, such as coral not being a rock or red pandas not actually being pandas. Thankfully, these 'myths' are explained along with some genuinely interesting information, such as the origin of the name 'red panda' and the science explaining why so much coral is currently dying in our increasingly warm oceans.

Alongside the text are fun illustrations by Ethan Kocak that help to bring certain facts to life. For example, an image of a female black widow reclining with a cigarette is the perfect way to illustrate the point about how most species don't actually eat the male after mating. We particularly enjoyed the image of a crazed-looking crab being controlled by a cheerful barnacle. What can we say – we love a bit of comedy with our science.

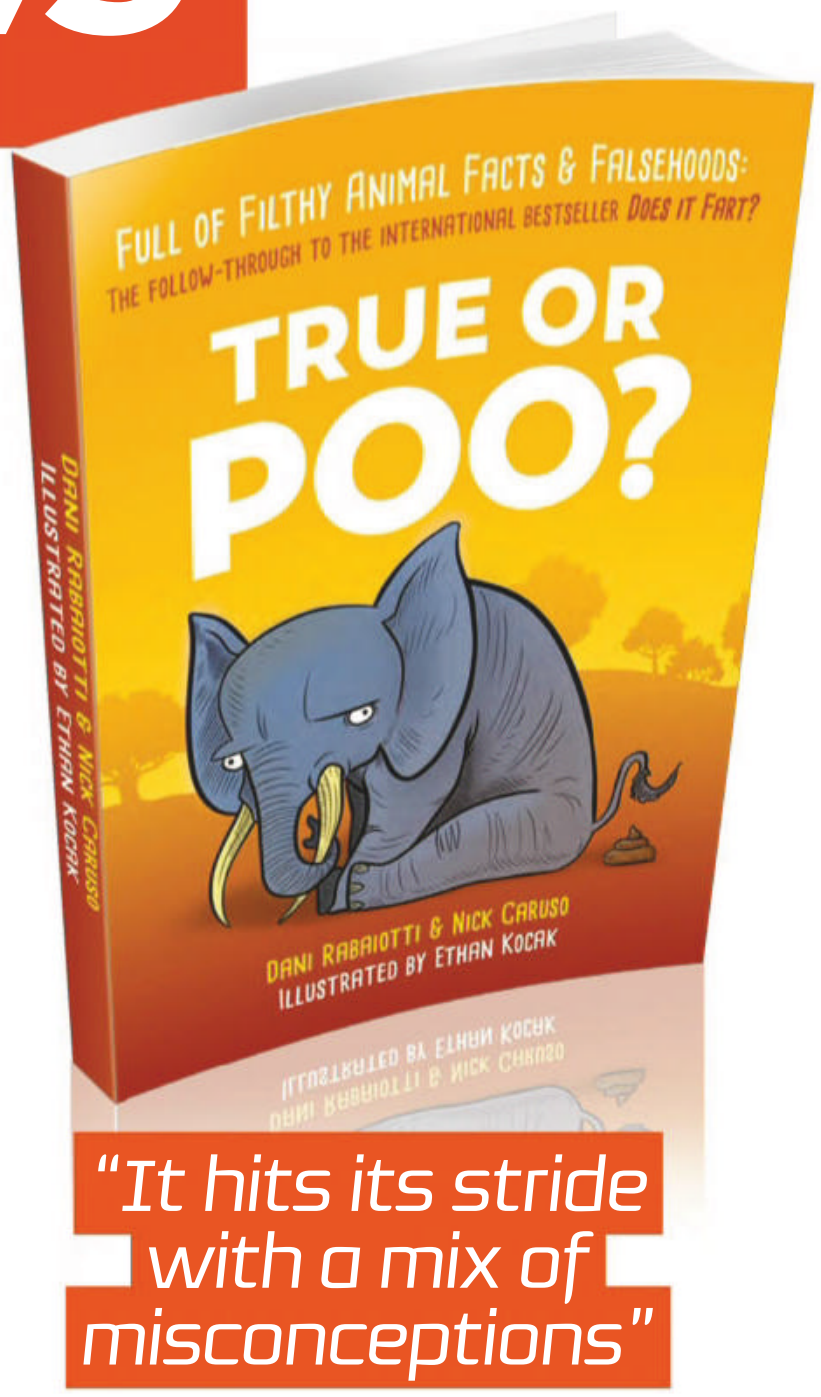
However, while this book is highly amusing, rest assured it has been penned by experts. Dani Rabaiotti is an environmental scientist and science writer based at the Institute of Zoology at the Zoological Society of London.

Her co-author Nick Caruso is studying for a PhD at the University of Alabama in the United States and was the brains (along with Rabaiotti) behind the excellently titled *Does It Fart?*, a "definitive guide to animal flatulence". Oh, he's also a salamander expert.

One thing to note is that the language in this book can be fairly complex at times, so this isn't one for young readers – at least not those without an adult on hand to explain some of the longer words to them.

Still, whether you're an adult looking for some facts to amaze your friends with or you're a curious youngster with a love of science, this is the perfect companion, one that will help you learn (and laugh) a great deal.

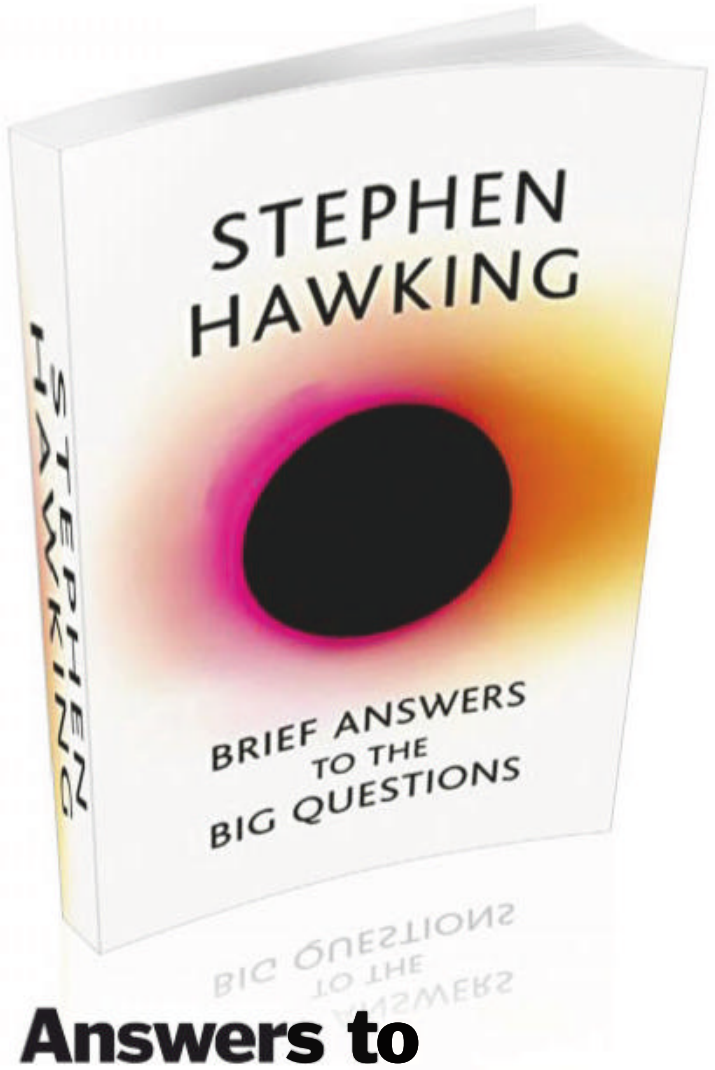
★★★★☆



"It hits its stride with a mix of misconceptions"

This pitcher plant is an eco-friendly toilet and feeding station for the moutain shrew

White sand is made of fish poo: we're never going to the beach again



Brief Answers to the Big Questions

The final thoughts

- Author: **Stephen Hawking**
- Publisher: **John Murray**
- Price: **£14.99 / $25**
- Release date: **Out now**

Finding new superlatives to ascribe to Stephen Hawking is a futile task, so we'll stick to what we know. A formidable scientist who overcame great personal adversity to become one of the most renowned scientists of the modern era, he lived his life as the face of science and will continue to do so even after his death.

Brief Answers to the Big Questions, his final book, works as an epilogue of sorts, providing, as the title says, his verdict on the kind of questions that have long given humanity pause for thought. It also functions as a recap. The opening chapter goes over his life, from his studies at Oxford to his first diagnosis and its debilitating effect on him, his marriage and life-defining studies.

It'll mostly be familiar territory, especially if you've seen *A Theory of Everything* (actor Eddie Redmayne – who contributes a foreword here – is described by Hawking as playing "a particularly handsome version of me") but is a suitable opener for what's to come.

From here the big questions are posed: is there life after death? Is time travel possible? Can we colonise space? Should we be worried about artificial intelligence? Especially in recent years, Hawking hasn't been shy about voicing his opinions on certain political matters, and indeed some of his answers to these questions have already been highly publicised. Even so, it's hard to disabuse the notions he comes up with. Given the complexity of the subject matter he worked in, his writing hasn't always been the easiest to decipher, but here it is perfectly pitched to as wide an audience as possible.

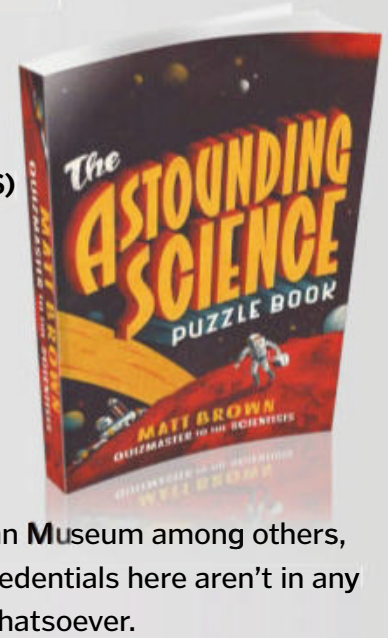
Moreover, the note he finishes on is a hopeful one. All in all, it's a fitting final chapter from one of the modern age's (if not all time's) most remarkable figures.

★★★★★

The Astounding Science Puzzle Book

The big fat quiz of the universe

- Author: **Matt Brown**
- Publisher: **Batsford**
- Price: **£9.99 / $14.95**
- Release date: **Out now (UK) / 1 January 2019 (US)**



Do you like pub quizzes but privately rage at the lack of science-themed questions? In the form of this book, you now have everything you need to start up your own test of trivia.

Granted, there's more to this than just random questions. From pop culture-themed sections ('The Science of the Beatles' is just one example) to tests like 'Name that constellation' and the reassuring presence of word searches, crosswords and the like, there's a lot here for boffins young and old to test each other. Author Matt Brown has previously hosted quizzes for the Royal Institution, Royal Society and Hunterian Museum among others, so his credentials here aren't in any doubt whatsoever.

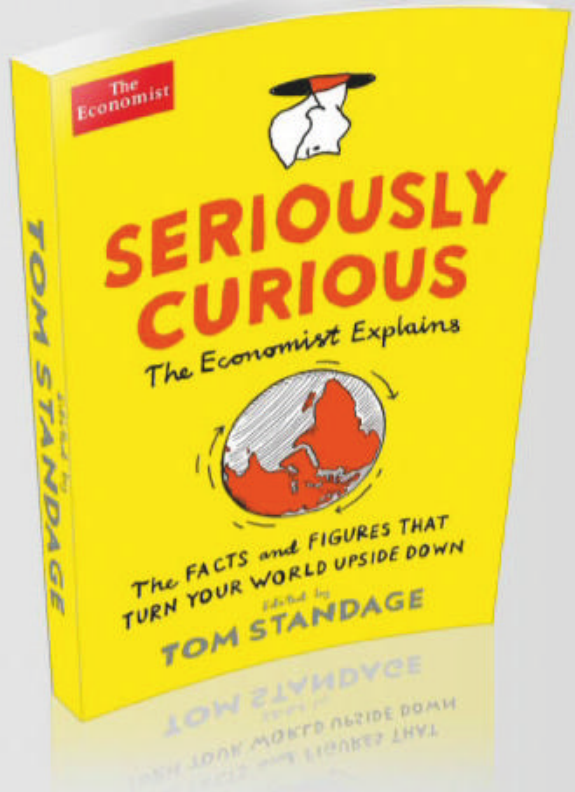
As with any quiz book, its appeal will invariably last as long as it takes for you to get through it. Whether you'll tire of it in that time is up for debate, but in the meantime the signs are good.

★★★★☆

Seriously Curious: The Economist Explains

Weird questions answered

- Author: **Tom Standage**
- Publisher: **The Economist Books**
- Price: **£8.99 / $17.99**
- Release date: **Out now**



How do car colours reflect the UK's national mood? What do people want at the end of life? Does polygamy make civil wars more likely? If you thought Stephen Hawking had some big questions to answer then wait until you see what the folks at *The Economist* have in store. If you haven't thought about it then they certainly will have.

A reliable indicator of editorial excellence, *The Economist*'s logo is a reassuring presence, and it's unlikely you'll be disappointed upon reading this. Displaying the kind of concise and erudite answers you would expect, every question is answered in a satisfactory manner, with even the seemingly frivolous questions providing ample food for thought.

More of a stocking filler than anything else, this is perfect bite-sized reading; something you can go back to again and again, without fear of forgetting the narrative arc. We recommend you give it a go.

★★★★☆

BRAIN GYM

GIVE YOUR BRAIN A PUZZLE WORKOUT

Wordsearch

W	B	W	A	A	Y	H	U	C	R	J	U	O	L	D
O	H	I	V	E	Q	W	Y	E	J	T	G	I	U	I
R	P	V	A	Y	A	I	K	J	K	H	Q	P	L	D
L	H	P	T	D	J	A	K	H	Y	O	Z	L	C	G
D	A	W	A	Y	E	G	R	J	R	R	F	A	R	E
L	R	U	R	R	S	Q	O	C	E	A	N	S	R	R
K	M	C	B	K	U	K	F	I	W	L	Q	T	W	I
S	A	E	J	R	I	C	K	R	J	F	K	I	I	D
L	C	F	X	E	S	G	T	T	Q	K	B	C	L	O
I	Y	V	V	P	A	L	A	C	E	L	W	J	D	O
E	X	B	Q	D	R	S	U	E	J	D	O	B	C	S
S	E	E	D	S	X	J	A	L	Y	T	N	J	A	W
L	V	U	G	Z	B	L	U	E	S	H	I	F	T	E
T	F	I	H	S	D	E	R	S	U	Q	H	Z	J	G
N	A	V	I	G	A	T	I	O	N	V	R	L	Q	X

FIND THE FOLLOWING WORDS...

AVATAR
BLUESHIFT
DIDGERIDOO
ELECTRIC
HIVE
ICEBREAKER
LIES
NAVIGATION
OCEANS
PALACE
PHARMACY
PLASTIC
REDSHIFT
RHINO
SEEDS
THOR
WILDCAT
WORLD

Spot the difference

See if you can find all six changes we've made to the image on the right

Quickfire questions

Q1 A mythical sphinx creature has...

- Eagle head, lion body
- Human head, lion body
- Human head, wolf body
- Lion head, human body

Q2 The Moon is ____ the size of Earth

- 14%
- 27%
- 33%
- 52%

Q3 Which is the world's second largest country after Russia?

- Australia
- India
- Brazil
- Canada

Q4 Which of these sports is played with the smallest ball?

- Squash
- Cricket
- Golf
- Tennis

Sudoku

Complete the grid so that each row, column and 3x3 box contains the numbers 1 to 9

EASY

		7		5	8	2	1	9
	1	5				6		
8		2	1	3	6		7	
1		6	5	9	4		3	
2	5					1		4
9	4	3		1	2	5	6	7
3	6		2				5	8
			6		5	3	2	1
	2	1		8	9	7	4	6

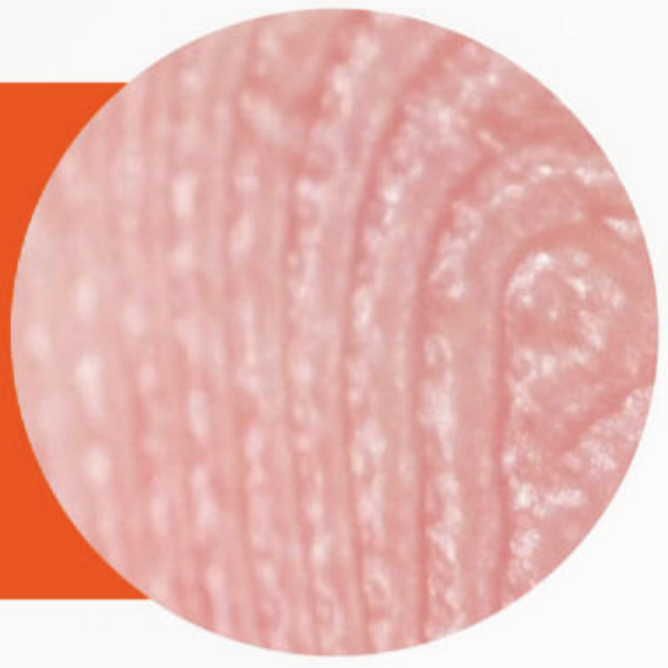
DIFFICULT

							4	
	8			7	4	6		1
	5	4			2			
		2						4
8			1			3		
9		5	4		8			7
	7			4				
	1		7	8				
							5	2

What is it?

Hint: No matter where you go, you'll always keep this close at hand.

A .....



© Getty

Spot the difference

Check your answers

Find the solutions to last issue's puzzle pages

Quickfire questions

Q1 Michael Collins

Q2 *White Christmas* by Bing Crosby

Q3 Murphy's law

Q4 False

What was it?

Eiffel Tower

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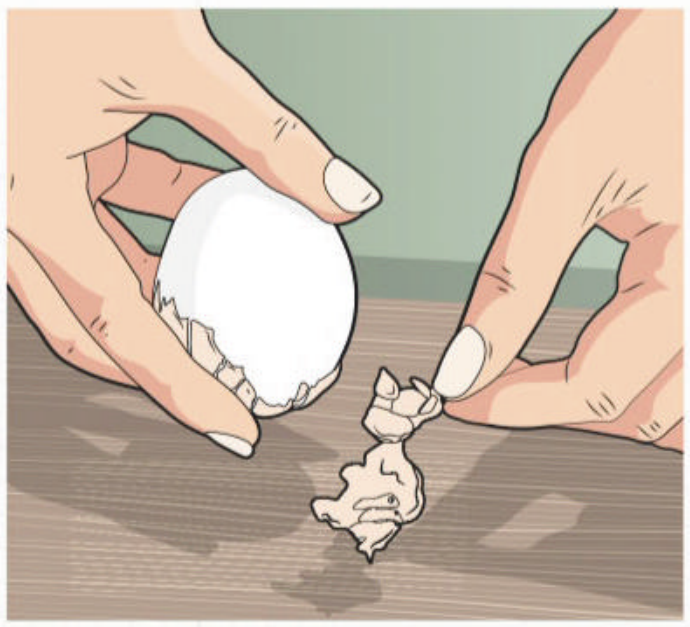
Get an egg in a bottle

Squeeze a hard-boiled egg into a bottle with the help of some smart science

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

1 Boil the egg

First you need to hard-boil the egg. Getting a raw egg into a bottle would be far too easy! Ask an adult to help you by boiling some water on the stove, then drop in the egg and leave it boiling for at least ten minutes.



2 Peel the egg

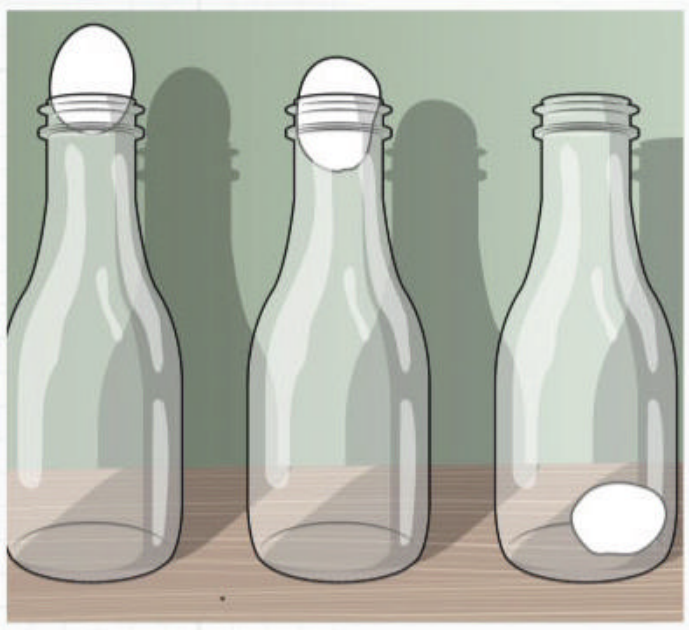
Once your egg has boiled and cooled, take it out of the water and carefully peel off the shell. You should be left with a rubbery egg that's hard all the way through. If you want to try the experiment a few times, boil more eggs.

3 Use some matches

Next, find a glass bottle with a neck that's narrower than the egg – it needs to be glass as plastic will melt. Carefully light at least three matches, and drop them into the bottle so that they don't go out.

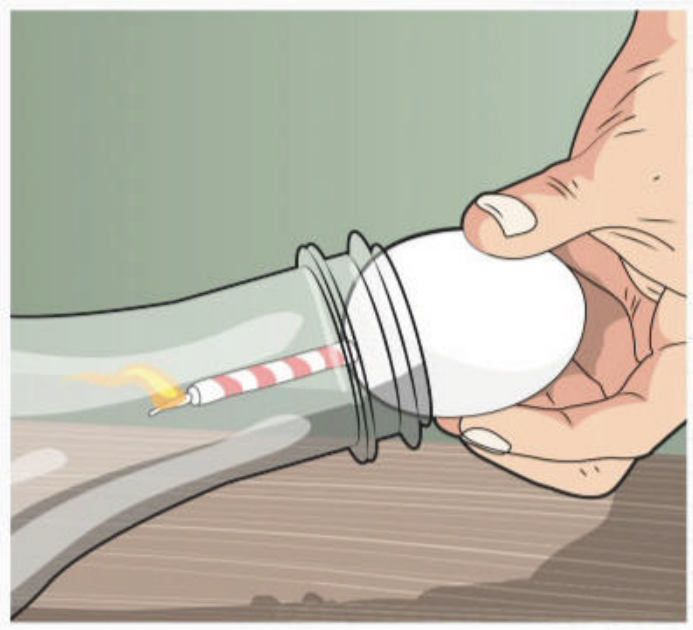
4 Act fast!

Before the matches burn out, place the egg on the top of the bottle with the wide end up. You don't need to push it down – just make sure the egg forms a seal around the neck of the bottle.



5 Watch it slide

The egg will start sliding into the bottle as the air pressure inside decreases and pulls it in. As it pops through, a rush of air will fill the bottle again, so the matches will probably go out.



6 Use a candle

You can also use birthday candles. Push two or three into the bottom of the egg, being careful not to break it. Then light them and place the egg on the neck with the bottle on its side.

SUMMARY...

When the egg forms a seal on the bottle the matches burn the remaining oxygen then go out. The air in the bottle cools quickly, and the volume of air decreases. This lowers the air pressure and because the air pressure outside is higher, the force overcomes the friction of the egg on the bottle neck and pulls it inside.

Had a go? Let us know! If you've tried out any of our experiments – or conducted some of your own – let us know! Share your photos or videos with us on social media.

NEXT ISSUE

Pour CO_2 onto a candle to put it out *(i.e. prove CO_2 is heavier than air)*

WIN SPHERO BOLT

This month we're giving away a Sphero BOLT – the app-enabled robot that makes coding fun. BOLT can be programmed to play games, interact with other BOLTS and zip around the racetrack.

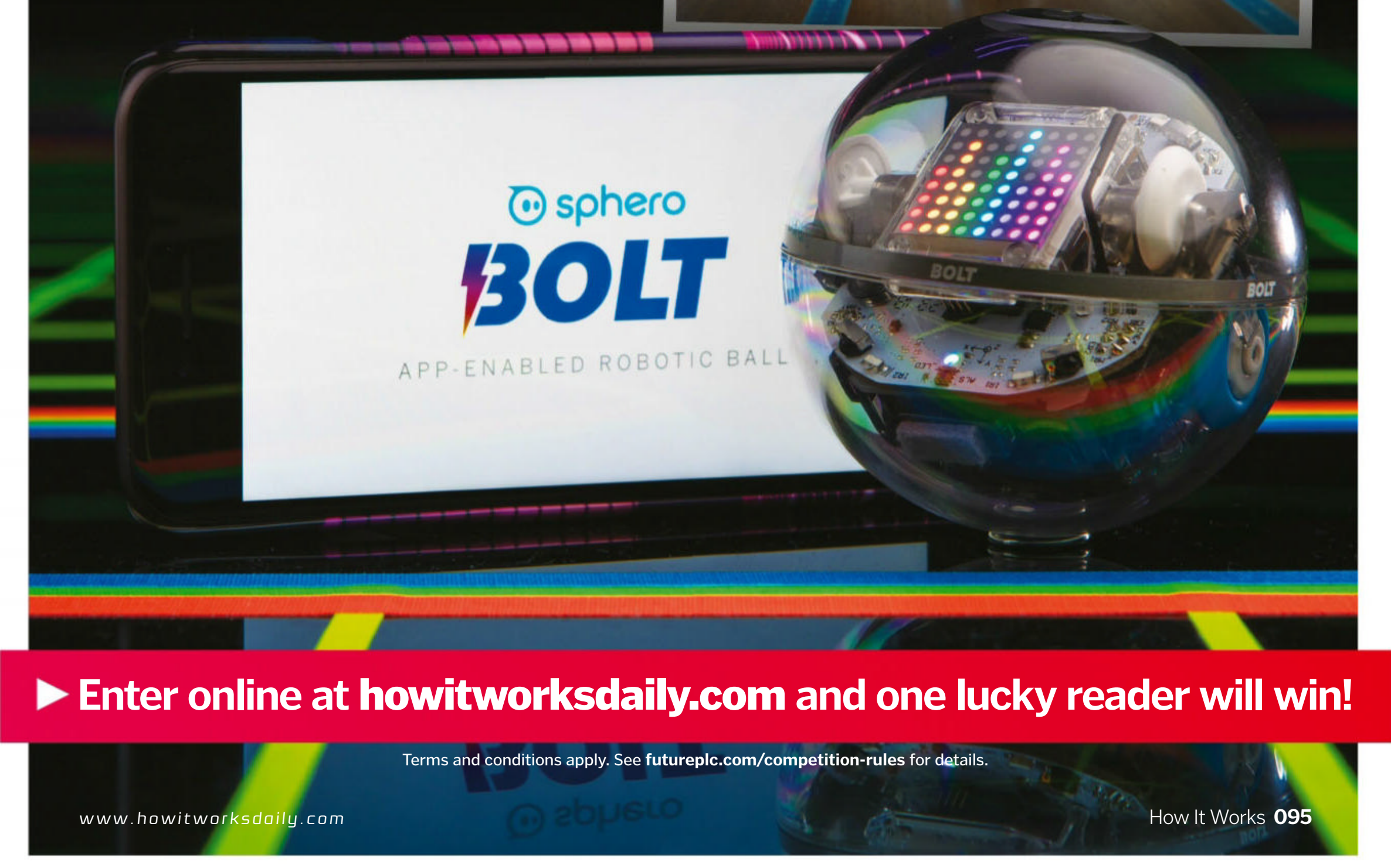
For a chance to win, just answer the following question on our website:

In which country would you find the Winter Palace?

a) **England** b) **Russia**

c) **Iceland**

WORTH £149.99!



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INBOX
Speak your mind...

Get in touch

If you have any questions or comments for us, send them to...

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This day is added to the calendar in leap years as a corrective measure because the Earth does not orbit the Sun in precisely 365 days

Letter of the Month

Shortest month of the year

Hi **How It Works Crew**,

My name is Alec Sherwin and I'm from Santa Barbara, California. I have been a subscriber to **How It Works** magazine for several years. My question is, "Why is February the shortest month of the year?" My main reason for asking the question is about leap years, as I have in the past felt bummed that I happened to be born in the shortest month of the year.

Thank you for considering my submission!

Regards,

Alec

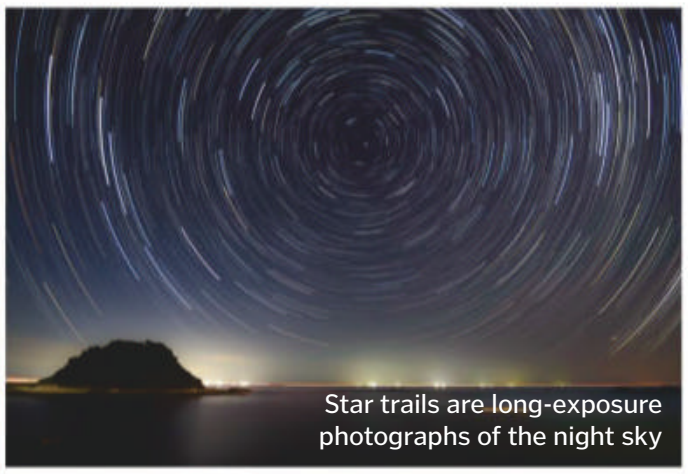
February is the shortest month of the year, with only 28 days. This is because our modern calendar is based on the Roman calendar. The month of February was added onto the Roman calendar by Numa Pompilius, the second king of Rome, in about 713 BCE, along with the month of January.

Before then, winter didn't have months because people didn't need to worry about planting or harvesting as they couldn't do that during the cold months. Numa (who ruled from 715–673 BCE) changed this, lining up the calendar with the year's 12 lunar cycles to have 355 days. He added two months, each 28 days long, but superstition dictated that even numbers were unlucky so he needed to keep one even to make 355 days.

February pulled the short straw – probably because it was the last month of the year at that time. Julius Caesar introduced the Julian calendar (with the help of his astronomer Sosigenes) in 45 BCE, keeping February 28 days long, and the leap day – the 29th of February that happens every four years to keep the calendar in sync with the seasons.

While it's commonly accepted that a calendar year lasts for 365 days, in actual fact a year lasts for precisely 365.242 days. Therefore it was necessary for the Romans to add on an extra day to the calendar every four years in order to ensure that annual festivals were held around the same time every year.

WIN!
AMAZING PRIZE FOR LETTER OF THE MONTH!
THE INCREDIBLE ATLAS OF THE HUMAN BODY
The winner of the letter of the month in our next issue will win a copy of this detailed colour atlas of each major organ and system of the human body.


Star trails are long-exposure photographs of the night sky

Telescope alignment

Dear **HIW**,

My dad uses a telescope to take photos of the stars, but he takes a long time aligning the telescope so that there are no star trails. How does the Hubble Telescope and the other telescopes in space maintain their alignment and produce pinpoint images of the stars?

Eti Lois

The big telescopes like Hubble maintain their alignment using Fine Guidance optical sensors, reaction wheels and gyroscopes to keep the telescope following its target. The Fine Guidance Sensors are optical sensors that point at the target and keep it in the telescope's view. The reaction wheels slowly move the telescope, while gyroscopes maintain orientation and provide stability so the picture doesn't blur. Smaller telescopes just aren't kitted out with this technology.

Spread the word

Dear **HIW**,

What is the difference between butter, margarine and lard? Thanks!

Louis Ireland

Butter, margarine and lard are all types of fat used in cooking. Butter is made by churning cream and used in baked goods like cookies and cakes, while margarine is made from vegetable oils and was invented in the 1860s as a cheap substitute for butter. Lard is a semi-soft animal fat taken from the belly of pigs. It can be used to make flaky pastries or for roasting potatoes.

Invisibility

Dear **HIW**,

If humans found some way to make themselves invisible by using different parts of the light spectrum, would some animals such as the mantis shrimp and snakes still be able to see us as their eyes can see other parts of the light spectrum?

Thanks,

Anouk Wood

Great question, Anouk! Some physicists think that it is possible that we might one day find a way to make ourselves invisible by using 'metamaterials' – materials that can bend electromagnetic radiations (such as light) around an object to make it look like it's not there at all. This wouldn't be using different parts of the light spectrum though, but instead moving the waves around the object. So you'll still be perfectly hidden from mantis shrimps and snakes.

We're not sure if physics will ever let us use a different part of the light spectrum the way you describe it, but hypothetically if we could, then you're right – other animals that can see other parts of the light spectrum would still be able to see us.

Until science can really make us invisible, we have to make do with clever illusions and tricks

What's happening on... social media?

This month, we asked you to come up with some of your own "What If" science scenarios, like "What if Earth fell into a black hole?"

"What if there was no gravity?"
@2Shelley09

"What If all the seas and oceans and rivers dried up??"
@greigo_uk

"what if there were no trees"
@pixiee1

"What if Star Trek type transporter/ teleportation machines existed: would the person arriving at the destination be the same person that left?"
@catlittertray

"What if the earth's temperature raised by 5degC average?"
@broboygibby

"What if the moon stopped spinning? What would Happen to tides and sea levels?"
@lauragibby1974

"What if we woke up one day and we could understand what animals were saying?"
@positiverachel8

NEXT ISSUE...
Issue 121 on sale **24 JAN 2019**

Available in print from all good newsagents and **myfavouritemagazines.co.uk**, or as a digital edition for iOS and Android. To enjoy savings on the RRP and to make sure you never miss an issue, check out our subscription offers on pages 30 (UK) and 83 (US).

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FAST FACTS

Amazing trivia to blow your mind

SUFFRAGETTE SOPHIA DULEEP SINGH WAS QUEEN VICTORIA'S GODDAUGHTER

OVER
4,000 PEOPLE
HELPED TO BUILD THE WINTER PALACE

2–3 METRES
THE THICKNESS OF MOST ARCTIC SEA ICE

THE SVALBARD GLOBAL SEED VAULT HAS THE CAPACITY TO STORE AROUND
2.25BN SEEDS

HYDROGEN MAKES UP MORE THAN
90%
OF ALL THE ATOMS IN THE UNIVERSE

EARTH'S CIRCUMFERENCE IS
40,075KM
AT THE EQUATOR BUT ONLY
40,008KM
FROM POLE TO POLE

THE WORD 'THURSDAY' DERIVES FROM THE OLD ENGLISH FOR 'THOR'S DAY', NAMED AFTER THE NORSE GOD OF THUNDER

A 2010 STUDY FOUND THAT PEOPLE TELL AN AVERAGE OF
1.65 LIES
EACH DAY

1 million
PLASTIC BOTTLES ARE PURCHASED EVERY MINUTE

THE MILKY WAY AND ANDROMEDA ARE MOVING TOWARDS EACH OTHER AT A SPEED OF OVER
400,000kph

A FULL-GROWN PARACERATHERIUM COULD WEIGH AROUND
20 TONS

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A model delivery

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AFTER WORKING WITH HIS FATHER IN agriculture, Edward Stobart started his haulage career using his father's delivery trucks and formed Eddie Stobart Haulage Company in 1976. From this point, Edward was able to grow his business into Britain's most recognised haulier, employing over five thousand people.

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